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Control Characteristics of Carbon Beds for Gasoline Vapor Emissions

Scott Environmental Technology, Inc, San Bernardino, Calif

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CONTROL CHARACTERISTICS OF CARBON BEDS FOR GASOLINE VAPOR EMISSIONS

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The samples tested are identified by code letter only in the test matrix in the Appendix and are not identified by manufacturer.

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DEFINITION OF TERMS

Charge	Flow of gasoline vapor and air mixture upward through carbon bed
Bleedthrough	Low concentration of unadsorbed vapor detected at outlet of carbon bed during charge
Breakthrough	Event when outlet vapor from carbon bed exceeds preset limit terminating charge
Hold	Period of inactivity after a charging or stripping mode
Strip (Purge Strip)	Flow of air down through the carbon bed to desorb hydrocarbons
Strip (Vacuum Strip)	Desorption of hydrocarbons by reducing the pressure in the carbon bed
Cycle	Repetitive sequence of charge, hold, strip, hold
Weathering	Gradual reduction in volatility of gasoline due to loss of higher partial pressure components
RVP	Reid Vapor Pressure (a measure of fuel volatility)
Total Charged Weight	Total weight of adsorbed vapor at breakthrough
Heel	Total weight of residual vapor not desorbed from carbon at end of strip mode
Working Capacity	Difference between total charged weight and heel
Acclimated	Condition of carbon achieved when the weight of the carbon has stabilized while being purged with constant moisture air
NDIR	Non-dispersive infrared (analyzer for hydrocarbons)
HC	Hydrocarbons
$C Cl_4$	Carbon tetrachloride
RH	Relative humidity

CONVERSIONS AND EQUIVALENTS

1 gallon	=	3.785 liters
1 inch	=	2.54 centimeters
1 pound/square inch	=	0.07 kilograms/square centimeter
1 inch H_2O (column)	=	0.00254 kilograms/square centimeter
1 inch H_2O (column)	=	0.073 millimeter of mercury (column)
1 pound	=	454 grams
1 foot	=	0.305 meters
1 cubic foot	=	0.028 cubic meters
1 grain H_2O/pound	=	0.0293 grams H_2O/kilogram
Temperature ^{o}F	=	^{o}C
-100 ^{o}F	=	-73^{o}C
- 10 ^{o}F	=	-23^{o}C
0 ^{o}F	=	-18^{o}C
36 ^{o}F	=	2^{o}C
49 ^{o}F	=	9^{o}C
50 ^{o}F	=	10^{o}C
69 ^{o}F	=	21^{o}C
75 ^{o}F	=	24^{o}C
86 ^{o}F	=	30^{o}C
90 ^{o}F	=	32^{o}C
100 ^{o}F	=	38^{o}C
150 ^{o}F	=	66^{o}C
200 ^{o}F	=	93^{o}C

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1.0 INTRODUCTION

Recently proposed regulations have specified emission controls which would reduce hydrocarbons entering the atmosphere from the marketing of gasoline. These emissions occur primarily from two modes of operation: bulk delivery of fuel to service station underground tanks and refueling of motor vehicles. Early control system designs operated on a pressure balance principle which simply meant that vapors were transferred back to the container being emptied, from the container being filled, through a separate vapor hose. The driving force for this vapor transfer was the small pressure difference between the containers. Early tests showed this approach worked well for the bulk delivery mode, however, during vehicle refueling vapors were not contained unless an adequate seal was maintained between the vapor recovery dispensing nozzles and vehicle fill necks. A wide variety of vehicle fill neck designs made the design of a sealing-type vapor recovery nozzle difficult.

Alternately, systems were designed with vapor blowers which generated a reduced pressure in the vapor recovery dispensing nozzle to suck vapors in when poor seals occurred. Excess air ingested into the vapor recovery system stimulated additional vaporization of the liquid fuel resulting in vapor growth situations. Systems were designed using activated carbon beds to capture and temporarily store these gasoline vapors with ultimate disposition of the vapors effected by incineration, condensation, and absorption techniques. Periodic regeneration of the carbon was deemed necessary to maintain a level of "working capacity" available for continuous use.

This program considered the practical working capacity of activated carbon to cyclically adsorb gasoline vapor which would otherwise be lost to the atmosphere such as during gasoline transfer operations at a service station. Quantitative measurements were made in the laboratory which were extrapolated to represent typical operation of a carbon control system at a service station pumping 50,000 gallons* of gasoline per month.

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*English-to-metric conversions, and equivalents presented on page iv.

Tests were performed on carbon from four manufacturers. Selection of the carbon materials used in this program was based on published performance specifications, commercial availability, bulk cost and suppliers' experience in using their products with gasoline vapor emissions. Previously vapor saturated carbon and different lots of the same carbon were tested. Three different granular mesh sizes were tested. The carbon was subjected to vapor from gasoline with and without lead and at two volatility levels. Tests were conducted at three ambient temperatures and three humidity levels. Two carbon bed lengths and two carbon bed cross-sectional areas were tested.

Vapor was desorbed at three air flow rates, three temperatures, two vacuum pressures and three vacuum temperatures. The ability of carbon to effectively adsorb vapor after 1000 cycles was determined. A complete specification of the test variables is presented in the Test Matrix in Appendix B.

4.0 PROGRAM SUMMARY

4.1 SUMMARY OF TEST RESULTS

Eight types of activated carbon from four manufacturers were evaluated to determine working capacity, basically defined as the amount of gasoline vapor which could be cyclically adsorbed per 100 grams of virgin activated carbon. Tests were conducted at various levels of fuel volatility, lead content, carbon bed shape, ambient temperature/humidity, purge air flow rate/temperature and vacuum stripping pressure/temperature.

A "baseline" set of conditions was established against which the effects of variables were compared. The "baseline" tests used a coal derived 12 x 28 mesh activated carbon material designated W-1 in a container which was approximately 13.3 cm (5.2 inches) tall by 6.5 cm (2.6 inches) in diameter. Gasoline vapors were generated by bubbling air at 75^{0} F, and 12% relative humidity through a leaded fuel having a volatility rating of 8.8 psi by the Reid Vapor Pressure (RVP) method. The vapors flowed upward through the carbon bed at 2000 cc/min. Charging of the carbon continued until a breakthrough level of 0.33% hydrocarbons (as propane) was observed in the effluent at which time charging ceased and the canister remained inactive for one minute prior to purging.

Purging was accomplished via countercurrent (downward) flow of 75^{0} F, 12% relative humidity air flowing at 4000 cc/min. When the effluent dropped to a concentration of 2.50% hydrocarbons (as propane), purging ceased and the carbon bed stood inactive for one minute prior to the next charge mode.

The test results indicated the following:

a) For eight "baseline" tests the working capacity averaged 6.03 grams of gasoline vapor per 100 grams of virgin activated carbon.

b) The working capacity was slightly lower on non-leaded fuel.

c) A high volatility fuel resulted in noticeably greater working capacity.

d) A carbon bed container twice as tall (same cross-sectional area) as the "baseline" case resulted in a slightly higher working capacity, and a container of twice the cross-sectional area (same height) had slightly lower capacity.

e) Air purge flow rates of five and ten times the "baseline" rate yielded slightly lower working capacities, however, purge times were approximately 1/5th and 1/10th the "baseline" time, respectively.

f) Heated purge air tests indicated no significant change in working capacity.

g) Higher relative humidities resulted in decreased working capacity.

h) Activated carbon exposed to extended periods of vapor saturation did not appear to be rendered inactive although the working capacity was decreased.

i) Working capacity decreased at lower ambient temperatures and increased at higher ambient temperatures for the same volatility fuel.

j) Vacuum stripping at 25 mm Hg absolute pressure resulted in lower working capacities than "baseline", however, preheating the carbon bed to 200° F. before stripping yielded higher capacities. Vacuum stripping at 100 mm Hg absolute pressure was ineffective.

k) Two samples of pelletized carbon having a larger particle size (lower mesh numbers) had slightly lower working capacity.

l) Working capacity appeared to vary directly with activated carbon specifications such as surface area (Nitrogen BET Method) and C Cl_4 activity and inversely with apparent density.

m) Different production batches of the same product were found to vary noticeably in performance.

n) The hydrocarbon residual or heel remaining on the activated carbon material after normal stripping techniques is comprised mainly of C_6 - C_9 compounds.

o) After 1000 operating cycles on one test carbon, working capacity was approximately 70 - 75% the capacity at the 20th cycle.

2.2 PROJECTION OF RESULTS TO A SERVICE STATION VAPOR CONTROL SYSTEM

The data obtained during this program can be very useful for determining the applicability of activated carbon adsorption systems for control of gasoline vapor emissions. Existing service station control systems using activated carbon all have capability for on-site regeneration although one of the earlier proponents of activated carbon envisioned periodic replacement of carbon beds and a centralized regeneration facility. This section of the report will briefly discuss the nature of the service station gasoline vapor emission problem and types of existing control systems and presents sample calculations of how to determine activated carbon requirements. For the following discussions, a typical service station is considered to be one pumping 50,000 gallons/month.

2.2.1 Service Station Vapor Emission Levels

Gasoline vapor emissions at service stations generally result from three modes of operation:

(a) Displacement of HC vapors from the underground storage tanks during bulk delivery

(b) Displacement of HC vapors from vehicle fuel tanks during refueling operations

(c) Accidental spillage of gasoline during refueling of vehicles

Additionally, gasoline vapors can be emitted in the form of "breathing losses" from storage tanks due to temperature and barometric pressure changes, regardless of whether or not there is any service station activity.

Early estimates and measurements of the quantity of vapors attributable to the various modes of activity vary considerably. The majority of the emission problem results from (a) and (b) both of which have been found to vary with gasoline temperatures, volatilities, flow rates, etc. However, estimates of between three and six grams vapor per gallon of fuel transferred cover most conditions. Estimates of spillage

losses and breathing losses are both on the order of 0.5 grams per gallon of throughput and obviously would be subject to large potential variations depending on conditions which influence their magnitude.

For the purpose of this discussion, potential emissions for categories (a) and (b) will be assumed to average 4.5 grams/gallon and potential breathing losses 0.5 grams/gallon. Spill losses may be influenced by attendant handling practices and hence may be beyond the control capabilities of any control system; however, proposed regulations in this area have been written to limit the number of spills per 100 refuelings.

A 50,000 gallon/month service station being supplied by an 8,500 gallon tank truck would receive deliveries at least every four to five days. During bulk delivery, approximately 8,500 gallons of vapor are displaced from the underground tanks. With most existing vapor control systems at least 90 percent of these vapors are displaced back to the emptied tank truck compartments leaving 850 gallons of vapor (at 4.5 grams/gallon) or 3825 grams of vapor to be controlled. If the compartments are unloaded at 400 gallons per minute and two products are unloaded simultaneously, then the entire unloading operation would take place in 10.6 minutes. The rate of loading on the control system would be 360 grams of vapor/minute.

To estimate typical vapor loading of the adsorbers during vehicle refueling many assumptions must be made. If one assumes that all of the vapor displaced from the vehicles refueled is collected by the system and that excess air is ingested at a rate equal to 20% (conservative), then for every ten gallon fill ten gallons of vapor and two gallons of air will be drawn into the system and ten gallons of liquid fuel leave the system. The two excess gallons of air can create additional vaporization of liquid in the underground tank so that about three gallons of excess vapor-air mixture may result from each ten gallon refueling. Again, it is emphasized that numerous factors such as temperature, fuel volatility, collection blower

setting, piping configuration and dispensing nozzle design affect this ratio, however, three gallons of excess vapor-air mixture per ten gallons dispensed is believed to be a reasonable estimate. Therefore, a potential loading of the adsorber equal to 13.5 grams HC per ten gallon fill is assumed and 2125 gallons/day (8500 gallons/four days) is dispensed at the typical service station. Loading of the adsorber would be 2869 grams/day (13.5/10 x 2125).

Based on the above assumptions, it would appear that the adsorber needs to be sized for the bulk delivery load of 3825 grams and that periodic regeneration modes after each refueling operation would insure that maximum adsorber capacity is available any time a bulk delivery arrives. In actual practice, most operating systems do regenerate after each refueling operation.

2.2.2 Sizing of Activated Carbon Adsorbers

Among the numerous factors which affect the design of a service station vapor control system are:

- Emission control capability
- Costs: capital, operating and maintenance
- Safety
- Reliability

Assuming that there are minimum acceptable standards for safety and reliability of a control system, there still exists a large potential latitude of design associated with controlling "X" amount of hydrocarbon vapors for "Y" dollars. The following discussion is not intended to cover the subject of cost effectiveness or cost tradeoffs for various system designs.

The previous subsection of this report presented typical values for tank truck capacity, gasoline vapor density, displacement efficiency and gasoline delivery rate to estimate the typical loading conditions that an activated carbon adsorption system might encounter. Variations in actual loading due to variations in operating condition is inevitable, however, data is not available to predict the emission rate for various combinations of variables. Similarly, the subject program attempted to identify the working capacity of various activated carbon materials in conjunction with fuel volatility, lead content, strip technique/temperature, canisters shapes, etc. Because of the limited number of actual tests

performed, performance data often must be projected from one set of conditions to another. Readers of this report are hereby cautioned that projected results should be substantiated with additional testing prior to making serious commitments.

To determine the amount of activated carbon required to adsorb a known weight of gasoline vapors, one would apply the general formula:

WTCARB = 100 WTVAPR/WORKCAP

WTCARB = Weight of activated carbon required, grams

WTVAPR = Weight of gasoline vapor to be adsorbed, grams

WORKCAP = Working capacity of activated carbon, grams vapor/ 100 grams activated carbon

The working capacity of the activated carbon can vary due to conditions beyond the control of the system designer such as ambient conditions, fuel composition, manufacturing variations. Table 1 shows the working capacities for a "baseline" set of conditions and provides an indication of the relative change in working capacity with changes in the uncontrolled variables. Since worst case conditions are bound to occur, the designer must size his adsorber accordingly. As indicated, adverse conditions could theoretically reduce the working capacity from 6.01 to 3.31 grams vapor per 100 grams activated carbon. Mathematically combining the percent reductions in working capacity for the three adverse cases may provide a distorted picture of the worst combination due to synergistic effects or cancellation of effects. For example, since the relative humidity is a function of ambient temperature, 80% relative humidity at 75° F. would contain about 2½ times as much water as 80% relative humidity at 50° F. In this regard, it would be advisable to investigate more completely the activated carbon characteristics in low temperature, high humidity environments rather than to evaluate the variables separately.

Table 1

REDUCTION IN ACTIVATED CARBON
WORKING CAPACITY AT ADVERSE CONDITIONS

Condition	Standardized Working Capacity in Grams Vapor per 100 Grams Activated Carbon
Baseline conditions on W-1 carbon; i. e., 75° F. ambient temperature, 12% relative humidity, 9 psi Reid Vapor Pressure leaded fuel	6.03
(a) At 50° F. (% reduction from baseline)	5.67 (6.0%)
(b) At 80% relative humidity (% reduction from baseline)	4.68 (22.4%)
(c) With unleaded fuel (% reduction from baseline)	5.15 (14.6%)
Net effect of all reductions from baseline	3.76 (37.7%)

A number of factors investigated during this program such as stripping method, stripping rate, stripping temperature and container shape give a designer certain flexibility to optimize the working capacity of the activated carbon. Table 2 shows how these factors could theoretically be exploited. Again, we end up at a combination of conditions that were not directly evaluated during this program and which should be examined in more depth to confirm the assumption. Referring back to general equation WTCARB = 100 WTVAPR/WORKCAP, a 3825 gram load would require 42,833 grams of activated carbon Y-1 (94 lbs.) for control. At 0.274 grams/cc density this would equal 156,325 cc (5.52 ft.^{3}) of material required to handle the bulk delivery.

The aforementioned projections do not take into account either degradation in working capacity with time or designing in a safety factor (or overcapacity) to accommodate atypical conditions.

Table 2

INCREASE IN ACTIVATED CARBON WORKING CAPACITY WITH SYSTEM DESIGN AND CARBON SELECTION

Condition	Standardized Working Capacity in Grams Vapor per 100 Grams Activated Carbon
Baseline condition on W-1 activated carbon; i.e., 75° air strip, strip rate 10 bed volumes per minute, canister shape has height/ diameter of 2:1	6.03
(a) With 150° air strip (% increase)	6.40 (6.1%)
(b) With 200° vacuum strip (% increase)	6.78 (12.4%)
(c) With canister shape h/d of 4:1 (% increase)	6.77 (12.3%)
(d) With Y-1 activated carbon (% increase)	11.35 (88.2%)
Net effect of increases from (b), (c) and (d)	14.32 (137.6%)
Net effect of factors (a), (b) and (c) from Table A with (b), (c) and (d) from this Table	8.93 (48.0)

Both the air strip and vacuum strip techniques appear to have the capability for further increasing the working capacity. The relatively unimpressive performance on the hot air strips resulted from not allowing the carbon to cool off prior to successive charges. The choice of which particular strip technique is to be used essentially determines the means of recovering or disposing of the hydrocarbons.

One of the most important considerations in system design is obviously cost. Initial cost estimates from the various suppliers indicated activated carbon costs of $0.54 - $0.88 per pound. Being relatively inexpensive, it is apparent that increasing the size of the adsorber 50%, for example, from 94 pounds carbon to 141 pounds carbon may be significantly less costly than incorporating certain hardware items which improve working capacity.

2.0.3 Disposition of Hydrocarbons

Current in-use systems which utilize air stripping either incinerate the hydrocarbon/air mixture in a direct flame burner or in a catalytic oxidizer. Table 3 shows the percent hydrocarbons in the stripped gas as a function of time during a typical 16½ minute strip mode (from test 3, cell #1). The theoretical proper mixture for combustion of these vapors is estimated to be 2.7% with a flammable range estimated to be from 7.8% to 1.6%. As indicated, a large amount of dilution air is needed for the first few minutes. By the tenth minute no more dilution air is theoretically required (although it is probably desirable). By the 16th minute, the concentration is near the lower flammability limit with no dilution air. A catalytic oxidizer would have the capability to continue oxidizing the stripped gas beyond the 16½ minute period.

The average concentration for the strip mode on Table 3 was about 7.5% gasoline vapors. With the concentrations characteristic of this stripped gas, condensation by refrigeration would require very low temperature possibly in the area of -100° F.

Stripping via a vacuum pump has the advantage of not diluting the stripped gas with dilution air. Although not measured during the course of this program, the HC concentration would be expected to be essentially 100 percent. The absence of air would make it possible to recover a sizable portion of these hydrocarbons by absorption in the underground tank (sparging) or condensation (either compression-refrigeration or straight refrigeration).

Table 3

TYPICAL HYDROCARBON CONCENTRATION PROFILE OF STRIPPED GAS DURING AIR STRIPPING

Time	Average Volume % Gasoline Vapor
0 - 1 min.	35.3 est.
1 - 2 min.	19.2
2 - 3 min.	12.7
3 - 4 min.	9.3
4 - 5 min.	7.1
5 - 6 min.	5.7
6 - 7 min.	4.7
7 - 8 min.	4.0
8 - 9 min.	3.4
9 - 10 min.	2.7
10 - 11 min.	2.4
11 - 12 min.	2.3
12 - 13 min.	2.1
13 - 14 min.	2.0
14 - 15 min.	1.9
15 - 16 min.	1.8
16 - 16½ min.	1.7

2.2.4 Service Station Vapor Control System Costs

As of the writing of this report, three types of control systems using activated carbon were in use at service stations. One system employs activated carbon to temporarily store captured vapors which are subsequently air stripped and burned by direct incineration. A second type differs primarily in that a catalytic oxidizer is used to dispose of the vapors. The third type incorporates a refrigerated condenser to liquefy part of the excess vapors, the noncondensable portion being captured by the activated carbon. Vacuum stripping periodically removes the adsorbed vapors at which time they are injected in the chilled condensate for return to the underground tank.

Table 4 presents data on relative cost factors for the various types of systems. Although there is disparity between annualized capital costs, operating costs and estimated control efficiency, cost effectiveness figures of approximately $0.20 per pound of HC controlled are indicated.

Table 4

COST EFFECTIVENESS OF VAPOR CONTROL SYSTEMS WITH ACTIVATED CARBON

System Type	Annualized Cost, $/Yr.	Refueling HC Controlled, Tns/yr.	Bulk Delivery HC Controlled Tns/yr.	Control Effectiveness $/Tn.
Carbon Adsorption w/ Direct Incineration	$2,795	7,569	7,137***	0.350
Carbon Adsorption w/ Catalytic Oxidation	$2,951	7,569	7,137***	0.203
Carbon Adsorption w/ Refrig. Condensation	$3,304	7,569	7,137***	0.224
Refrig. Condensation	$1,252	3,761	2,554	0.338

*Information extracted from "Cost Analysis--Service Station Emission Controls (Vehicle Refueling)", March 5, 1976, Conoco, Process Engineering Department, Ponca City, Oklahoma. Data is applicable to a 60,000 gal/mo. station and assumes 90% control of vehicle refueling emissions (@ 5 gms/gal) and 100% control of diurnal breathing losses.

**Information extracted from APCA Paper #75-54.1 "Cost Effectiveness of Gasoline Vapor Recovery Systems." Presented at 68th Annual Meeting June 15 - 20, 1975/ Data is applicable to a 40,000 gal/mo. station and assumes 96.3% control of all service station emissions. Paper does not state whether or not activated carbon is used.

***Assumed to be 90% control based on 5 gms vapor/gallon of fuel delivered.

3.0 EXPERIMENTAL PROCEDURES AND RESULTS

In this section the individual test results and the procedures followed will be discussed in detail. Full and complete evaluation of the parameters of interest for the four basic types of carbon would have required many thousands of individual tests. The data obtained during this program represent an initial step toward evaluating activated carbon performance characteristics, however, additional effort is indicated to quantify carbon working for certain combinations of adverse or optimum conditions.

A tabulation of the test results is shown in Appendix A, and the matrix of test conditions for each individual test is contained in Appendix B.

3.1 REPEATABILITY-BASELINE TESTS

The working capacity of one carbon was measured eight times under identical conditions. One hundred sixty grams of type BAM carbon was charged with leaded nine pound RVP (nominal) gasoline vapor at 2000 cc/min. and stripped at 4000 cc/min. with 75°F air. The 12 x 28 mesh carbon was tested in a 65 mm diameter, 133 mm tall canister. The pressure in the canister was held at atmospheric during both charge and strip. These same conditions were established on all four canister weighing test stations. Only the actual gasoline volatility was subject to minor but unavoidable differences due to weathering. The concentration of gasoline vapor was measured for each test. Moisture content in the charge-strip air was held constant by saturation at 36°F in a moisture trap. The activated carbon was acclimated to this same moisture level prior to initiating each test.

Test results are tabulated in Table 5. The average value for working capacity was 6.03 grams of gasoline vapor per 100 grams of activated carbon with an average gasoline vapor concentration of 53.6 volume percent (measured as propane).

Table 5
CARBON WORKING CAPACITY - BASELINE TESTS

Carbon Type	Test No.	Date 1976	Observed Working Capacity gm/100 gm	Vapor Concentration, Volume % as C_1
W-1	1-1	8/20	6.08	62
W-1	1-2	9/17	6.78	62
W-1	2-1	8/20	6.89	65
W-1	2-6	9/2	6.06	60
W-1	3-1	8/20	6.91	66
W-1	4-1	8/20	6.17	63
W-1	4-2	8/23	6.17	64
W-1	4-14	9/13	6.44	59
	Mean Baseline		6.03	63.6
	Standard Deviation		0.22	

3.2 EFFECT OF GASOLINE COMPOSITION

2.3.1 Lead Content

Prior to performing tests of activated carbon working capacity, an experiment was performed to quantify the effect of lead compounds (from gasoline anti-knock additives) in the gasoline vapor. Two canisters containing approximately 160 grams of activated carbon were subjected to 80 cycles of operation (approximately 3.84 m^3 of gas). Vapors flowing into one canister originated from a commercial premium fuel having a lead content of 2.79 grams/gallon, and vapor to another canister was generated from a commercial unleaded fuel with a lead content of 0.017 grams/gallon. A third canister was supplied an equivalent amount of vapor free air.

The amount of lead on the activated carbon, determined by spectrographic analyses, indicated that minute quantities of lead compounds present in the vapors were depositing on the carbon as shown in Table 6. Accumulation of lead at the maximum rate of 16.5 μ grams/gram for 80 cycles of operation indicates that it would take about 1500 cycles to accumulate enough lead to have a measurable influence on the working capacity weight measurements.

3.2.2 Leaded vs. Unleaded Fuel

As mentioned previously, eight replications of the "baseline" test conditions were conducted using leaded fuel and carbon designated W-1. Similarly, the same conditions were used twice in evaluation of carbon X-1. Tests performed on each of these two carbons using unleaded fuel resulted in decreases in working capacity from 9 to 14% as shown in Table 7. One possible explanation for this effect is that high octane compounds such as aromatics (benzene, toluene, xylene) are present in higher percentages in the unleaded fuel. The ring-like structure of these aromatics may require higher energy levels to remove from the carbon micropores, hence less are desorbed under normal stripping techniques.

Table 6

EVIDENCE OF ADSORBED LEAD

Carbon Type	Total Adsorbed Lead μ gm/gm	Gasoline Specifications Lead GM/Gal	Nominal RVP lb.
Z-1	3.6 ± 0.1	0.017	9
Y-1	16.5 ± 0.1	2.79	9
Y-1	0.88 ± 0.05	(Vapor Free Air Only)	

3.2.3 Effect of Volatility

A high volatility unleaded fuel was obtained from a specialty fuel refiner for comparison with the 9 psi RVP fuels. These data, shown in Table 7, indicate working capacities of 27% and 29% greater with the 14 psi unleaded fuel over the 9 psi RVP unleaded fuel for the W-1 carbon and the X-1 carbons, respectively. Figure 1 presents the results graphically. Butanes are usually added to gasoline to increase volatility and are a major constituent of the vapor-air mixture. The activated carbon appears to easily adsorb and desorb these relatively small molecules resulting in higher working capacities for the higher volatility fuel.

With changes in working capacity due to fuel volatility being more pronounced than had been anticipated, it was desirable to "correct" test results to a common volatility base. To accomplish this correction, gasoline vapor concentration was used as the indicator of fuel volatility since actual RVP tests were performed only on the fresh, as-received fuel.

Table 7

FUEL COMPOSITION EFFECTS ON WORKING CAPACITY

Carbon Type	Test No.	Observed Working Capacity gm/100 gm	Vapor Concentration, Vol %	Reid Vapor Pressure, psi	Lead Content gm/gal
W-1	Baseline*	6.03	53.6	8.8	2.79
W-1	4-10	5.19	55	8.7	0.017
W-1	4-5	6.69	98	13.8	0.003
	% Change in Working Capacity = (6.03 - 5.19)/6.03 = 13.9% decrease for unleaded				
	% Change in Working Capacity = (6.69 - 5.19)/5.19 = 28.9% increase for high RVP				
X-1	1-5, 4-11	5.52 avg.	52.5 avg.	8.8	2.79
X-1	3-10	5.04	56	8.7	0.017
X-1	4-7	6.38	94	13.8	0.003
	% Change in Working Capacity = (5.52 - 5.04)/5.52 = 8.7% decrease for unleaded				
	% Change in Working Capacity = (6.38 - 5.04)/5.04 = 26.6% increase for high RVP				

*Data shown is average for eight baseline tests

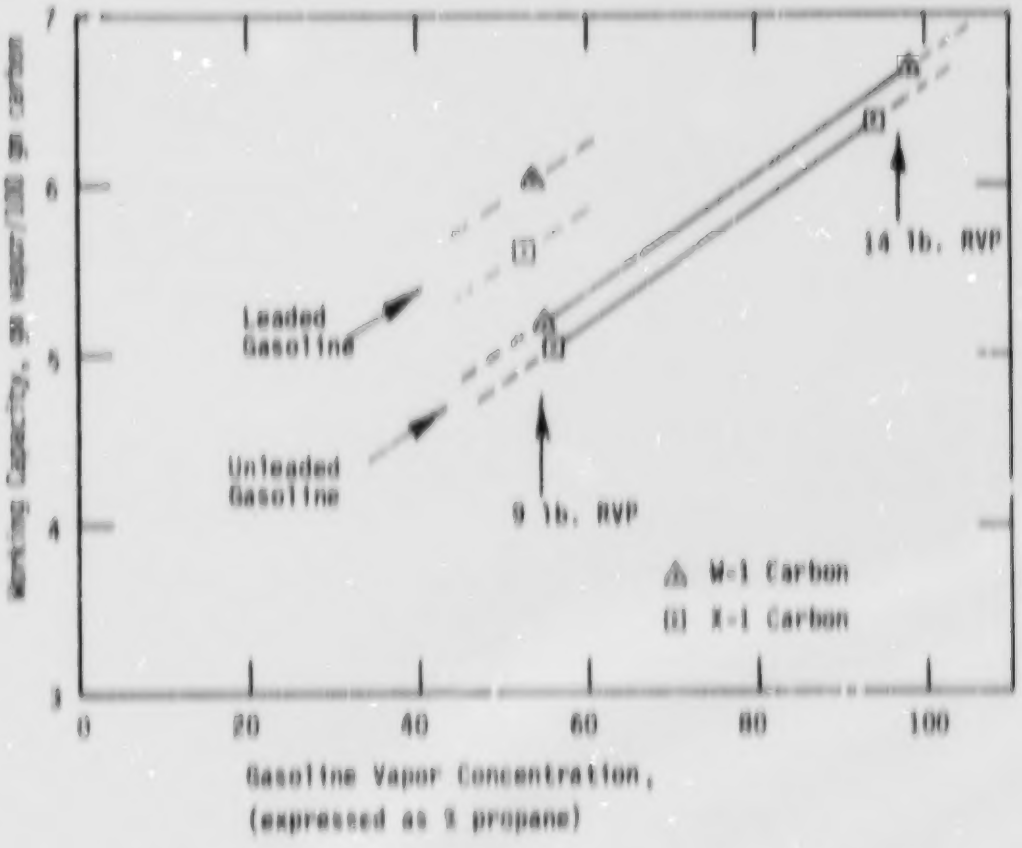


Figure 1
FUEL COMPOSITION EFFECTS ON WORKING CAPACITY

The slope of the volatility trend line for W-1 carbon in Figure 1 was used to correct the data to 53.6% when 9 RVP fuel was used and to 98% vapor concentration when 14 RVP fuel was used. The slope of this line is:

$$0.0338 \frac{gm/100\ gm}{\%\ conc_0}$$

For nominal 9 pound RVP tests, the data are corrected to 53.6%, therefore:

$$WC_c = WC_0 + 0.0338\ (53.6 - \%\ conc_0)$$

Where:

WC_c = corrected working capacity

WC_0 = observed working capacity

$\%\ conc_0$ = observed vapor concentration

For nominal 14 pound RVP tests, the data are corrected to 98.0%, therefore:

$$WC_c = WC_0 + 0.0338\ (98.0 - \%\ conc_0)$$

Since the above correction equations are based on just two levels of volatility, the linear approach was the only feasible method, however, a curvilinear relationship probably exists. The equations were used during the data analysis to minimize variability in the program test results and should not be applied to any situations or conditions other than the subject test data. All further references to working capacity test results in this report should be interpreted as corrected working capacity unless otherwise stated.

3.3 CARBON MANUFACTURERS

Working capacity was directly compared between activated carbons from four different manufacturers. The type, form and mesh size were nearly the same for the four samples. Moisture content in the samples was not the same. Before testing each sample was acclimated to be in equilibrium with the moisture in the charge and strip air. Important properties of each carbon are summarized in Table 8.

Table 6

CARBON PROPERTIES VS. WORKING CAPACITY

Test No.	Date 1976	Carbon Type*	Mesh	Surface Area m^2/gm	Density as Tested gm/cc	Activity % C Cl_4	Corrected Working Capacity gm/100 gm
(8 Baseline tests)		W-1	12x28	1000	0.380	68.7	6.03
1-11	9/7	W-2	8x10	1000	0.412	61.3	4.64
1-11	9/15	W-2	8x10	1000	0.412	61.3	4.99
1-12	8/25	W-3	4x6	1000	0.388	68.9	5.26
1-10	9/16	W-5	12x28		0.338		7.12
1-9	9/13	W-7	12x28	1100	0.447	66.4	4.52
1-5	8/19	X-1	8x30	960	0.452	63.8	5.49
4-11	8/19	X-1	8x30	960	0.452	63.8	5.62
1-3	9/2	Y-1	14x35	1200	0.274	80**	11.37
1-3	9/17	Y-1	14x35	1200	0.274	80**	11.36
1-4	8/27	Z-1	12x30	625	0.411	42.1	4.22

*See Appendix D for additional information on material

**Reported 60-100 % C Cl_4

The same mass of 160 gm of each acclimated carbon was placed in canisters and tamped to approximately the same compaction. The working capacity in grams of hydrocarbon adsorbed per 100 grams of acclimated virgin activated carbon are presented in Figure 2. Sample Y had nearly twice the capacity of Sample W and nearly three times the capacity of Sample Z. Sample X had slightly less capacity then Sample W. Complete specifications for the carbon samples tested are presented in Appendix D. Only Sample Y is a type made from wood. The other three are coal based. All four samples were granular in form. The estimated costs varied from $54 to $88 per 100 pounds depending on the quantity purchased. Sample W was received in a composition board drum with no apparent moisture barrier. Sample X was received in a steel pail sealed with a metal lid with no O-ring. Sample Y was received in a sealed metal can. Sample Z was received in a sealed collapsible plastic container.

3.3.1 Carbon Production Lots

Carbons from the same manufacturer with the same published specifications but from different lots were tested (designated W-1 and W-5). The second lot, W-5, had 18% greater capacity than the first. When actually measured, the acclimated densities of the first and second lots were found to be 0.38 and 0.34 respectively.

3.3.2 Carbon Particle Size

Activated carbons with differing particle size from one manufacturer were tested. Other properties were nearly the same. The two larger particle (lower mesh) carbons were in pellet form while the smallest had a granular form. All are coal based. The carbon with the smallest particle (highest mesh size) had the highest working capacity. The least capacity was exhibited by the middle mesh size while the largest particle (lowest mesh) carbon had a capacity between the two. Activated carbon is screened to establish a desired particle size distribution. A comparator scale shown in Figure 3 indicates relative particle sizes. Working capacity measurements for carbons with different particle size are presented in Table 8 and shown in Figure 4.

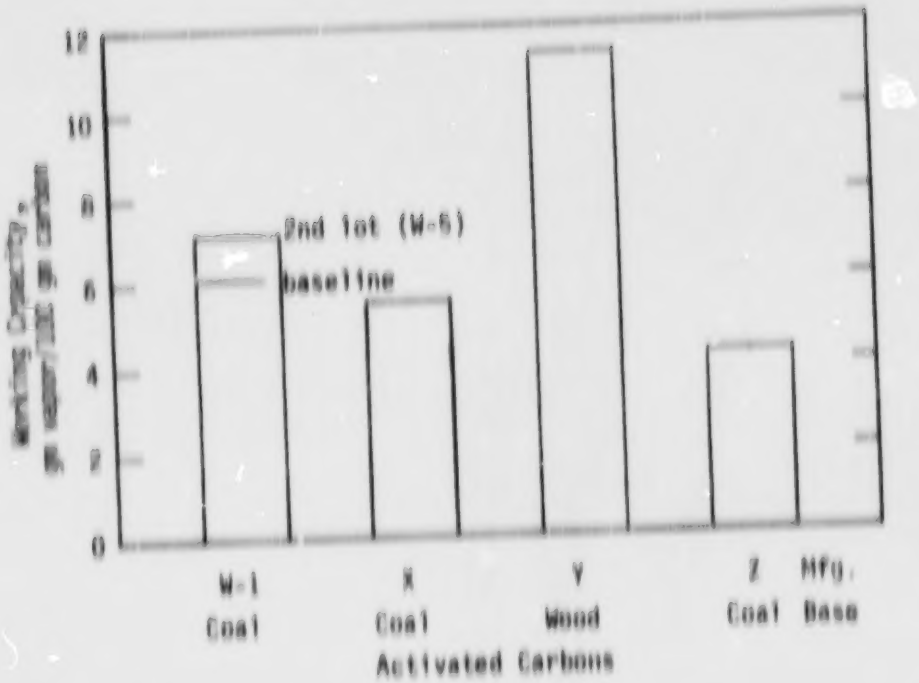


Figure 2
WORKING CAPACITY OF DIFFERENT CARBONS

STANDARD MESH		OPENING		PARTICLE
Tyler	U.S.	mm	inches	
4	4	4.76	0.187	
6	6	3.33	.131	
8	8	2.38	.094	
10	12	1.65	.065	
12	14	1.40	.056	
14	16	1.17	.047	
16	18	0.991	.039	
20	20	.833	.033	
24	25	.701	.028	
28	30	.589	.023	
32	35	.495	.020	
35	40	.417	.016	
42	45	.351	.014	
48	50	.295	.012	
60	60	.246	.0097	
80	80	.175	.0069	
100	100	.147	.0058	
150	140	.104	.0041	
200	200	.074	.0029	
270	270	.061	.0024	
325	325	.043	.0017	
400	400	.038	.0015	

Figure 3

ACTIVATED CARBON PARTICLE SIZE COMPARATOR

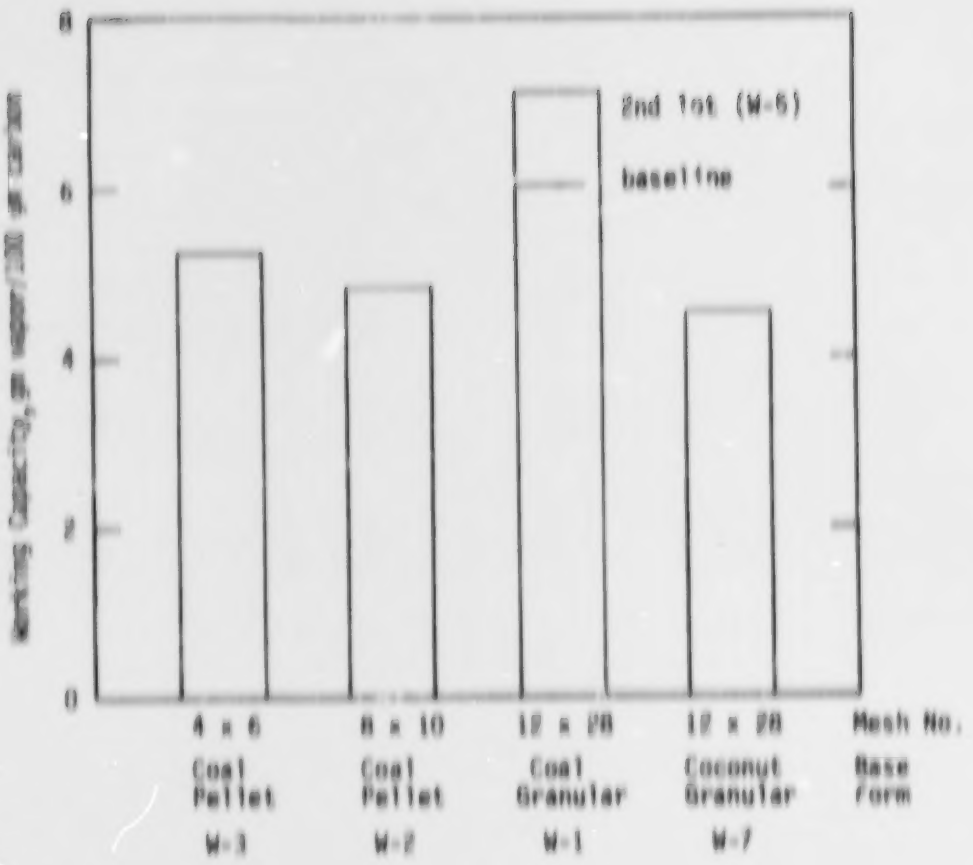


Figure 4
CARBON MESH SIZE AND FORM VS. WORKING CAPACITY

3.3.3 Surface Area

Activated carbon granules contain an internal micropore structure which exhibits an enormous surface area. The published surface areas vary widely between the different carbons. Working capacity as a function of surface area is listed in Table 8 and plotted in Figure 5. Samples W, X and Z are coal based carbons. Sample Y is a wood based carbon. The highest working capacity was obtained with the highest surface area, Sample Y.

3.3.4 Apparent Density

Activated carbon has an affinity for both hydrocarbon vapor and water vapor. Hydrocarbon vapor can be driven off during original activation and later during reactivation. Water vapor, however, may be adsorbed during (hot steam) activation. Moisture may also be adsorbed by activated carbon whenever it is exposed to the atmosphere and until it reaches equilibrium with the moisture level in the surrounding air.

The apparent bulk density of the carbons, as they were received for this program, varied from 0.31 to 0.46 gm/cc; the moisture level varied from 0.2 to 14.8% by weight (see Appendix D). Preliminary testing showed that widely varying moisture levels in the carbon could affect the gravimetric canister weight measurements. Dry carbon adsorbed both gasoline vapor and moisture during charge but desorbed only hydrocarbons during strip since the strip air had higher moisture than the carbon. Conversely wet carbon desorbed moisture during both charge and strip because both the charge carrier air and the strip air were drier than the carbon.

To minimize these effects, it was decided that the moisture level in both charge and strip air should be held constant. It was further decided that before test, the moisture in each carbon sample should be brought to equilibrium with the moisture in the charge and strip air so that the net weight change in the canister would be due only to the gain and loss of gasoline vapor.

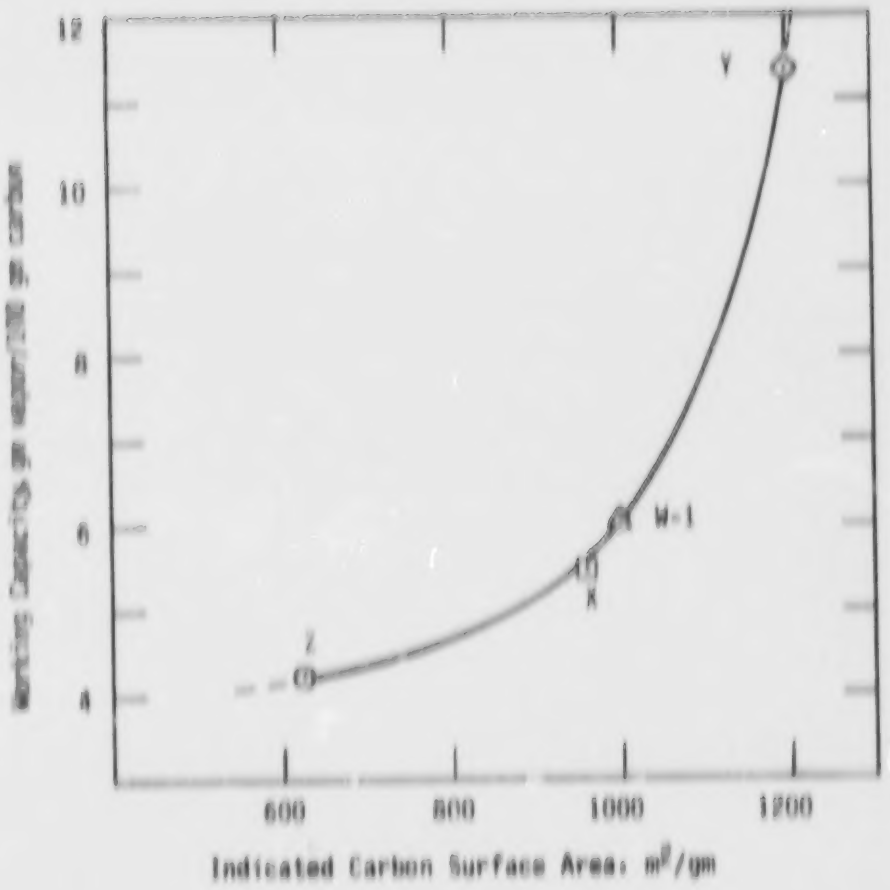


Figure 5
CARBON SURFACE AREA VS. WORKING CAPACITY

Moisture was controlled by the apparatus described in Section 4.2.5. The air was chilled in a moisture condenser to 36°F. Condensation in the bottom of the condenser trap maintained the relative humidity at 100%. When this air was delivered to the test apparatus, the temperature was raised to 75°F. The new relative humidity at these conditions was determined to be 12 ±2% from a psychrometric chart.

Each carbon was acclimated to equilibrium with this moisture level before testing. Finally a sample of each carbon was baked in a 150°C oven until no further weight loss could be detected. The density and percent moisture for each carbon, as published, as received, as acclimated before test and dry are presented in Appendix D.

The working capacity of each carbon as a function of density is presented in Figure 6. The units for working capacity are grams of hydrocarbon adsorbed per 100 grams of activated carbon acclimated to 12% relative humidity air. The units for density are grams per cubic centimeter of acclimated carbon. Working capacity is seen to increase strongly with reduced acclimated carbon density. One sample, X, fails to fit this characteristic. It is the heaviest of the samples and held the least moisture during test.

3.3.6 Carbon Activity

Published data for each carbon include the ability to adsorb carbon tetrachloride, $C Cl_4$. This ability is called $C Cl_4$ activity and is defined as the weight percent of $C Cl_4$ that can be adsorbed on the carbon. These data are listed in Table 5.

Working capacity as a function of $C Cl_4$ activity is plotted in Figure 7. Activity among the coal base carbon seems to have little affect on working capacity. The greater capacity of the one wood base carbon is distinguished by the highest $C Cl_4$ activity of the carbons tested.

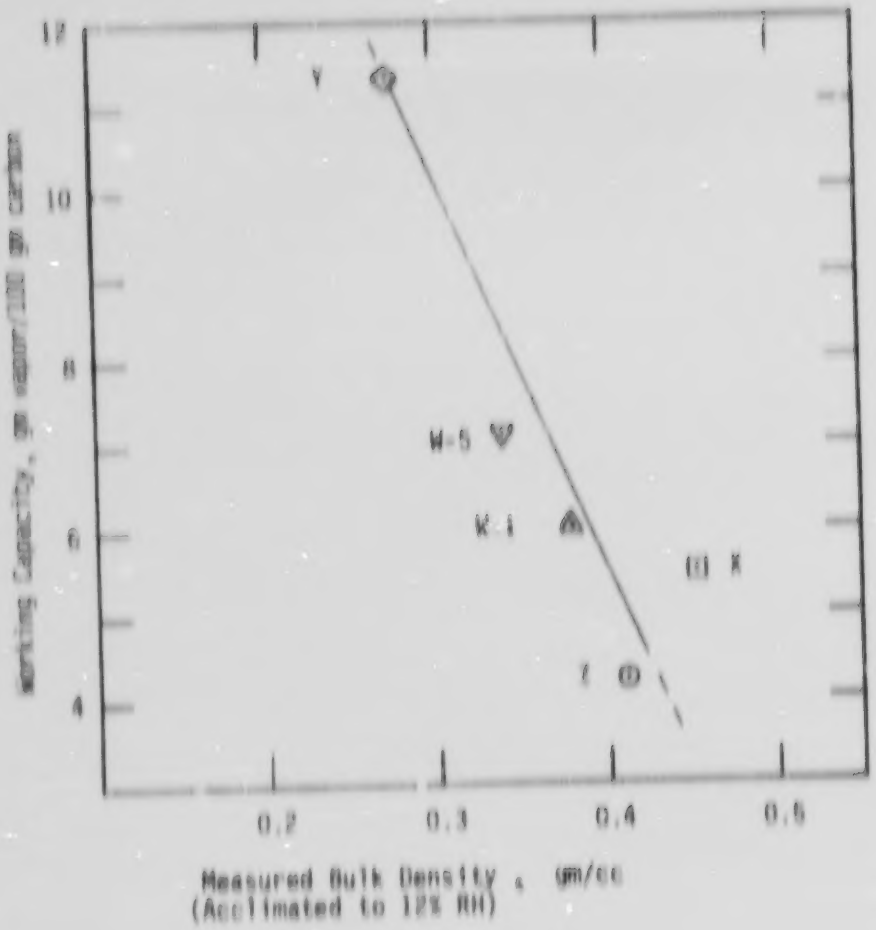


Figure 6
CARBON DENSITY VS. WORKING CAPACITY

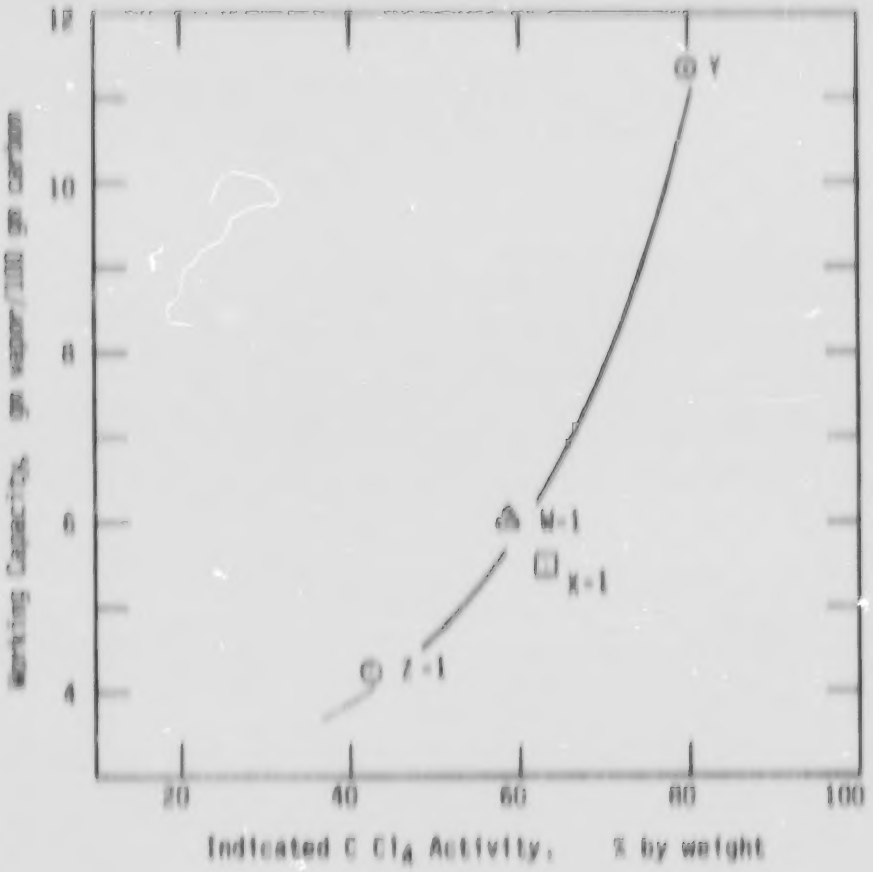


Figure 7

CARBON C Cl_4 ACTIVITY VS. WORKING CAPACITY

3.4 CANISTER DESIGN

Tests were performed on carbon beds having two configurations different from the baseline canister. One can had a cross-sectional area and diameter equal to the baseline can but was twice the length (height) and twice the volume. The other can had a length equal to the baseline can but was twice the cross-sectional area ($\sqrt{2}$ x diameter) and twice the volume. The L/D ratios were 4.0, 3.0 (baseline) and 1.4 respectively. Charge and strip flow rates were held the same as in the baseline tests.

Working capacity of the carbon in three different canister configurations is listed in Table 9, and results are shown graphically in Figure 8. In Figure 8 working capacity is seen to improve with increased L/D ratio within the range tested. The increased working capacity for the taller canister is explainable using Mass Transfer Zone (MTZ) theory. Basically, this means that the carbon bed, upon being charged, contains a zone which is fully saturated with hydrocarbons and a zone where the saturation level varies from full to empty as indicated at the top of Figure 9 . For all practical purposes, this zone contains half of its maximum capacity. Any additional hydrocarbons added to the bed will cause these zones to shift slightly and a breakthrough is detected in the effluent. Hence, the capacity at breakthrough of the example carbon bed is 75% of maximum capacity if the bed length is twice the length of the MTZ. Additional carbon bed length increases the capacity at breakthrough as shown at the bottom of Figure 9.

Table 9

CANISTER CONFIGURATION EFFECTS ON WORKING CAPACITY

Test No.	Can Config.	Area, cm^2	L/D	Charge Velocity cm/sec	Corrected Working Capacity, gm/100 gm
2-3	HxZA	66	1.4	0.5	6.77
(Baseline)	HxA	33	2.0	1.0	6.03
2-2	ZHxA	33	4.0	1.0	6.77

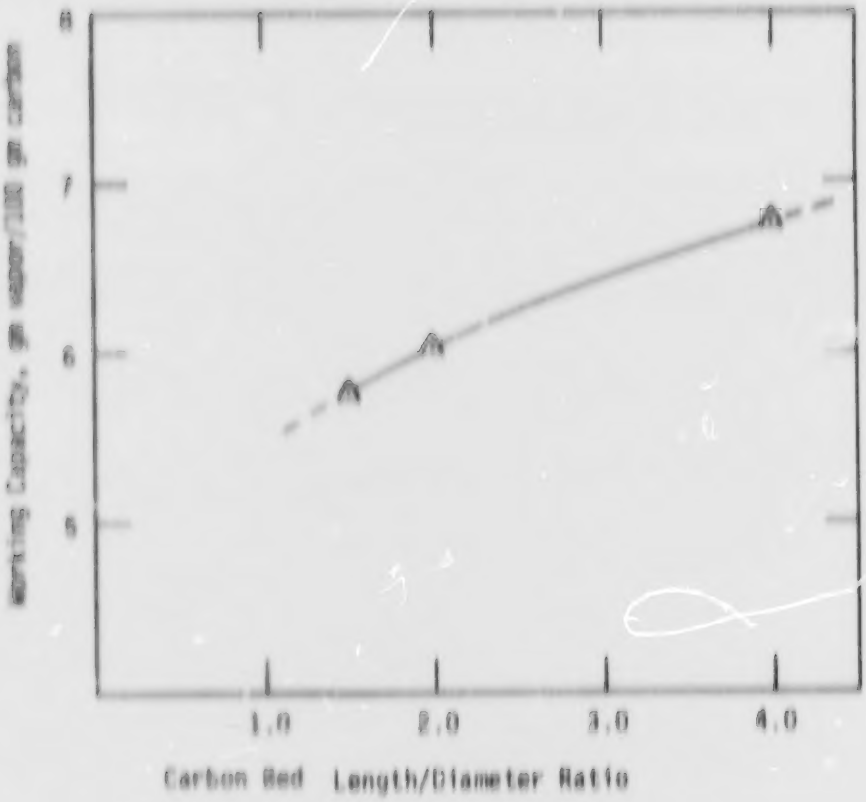
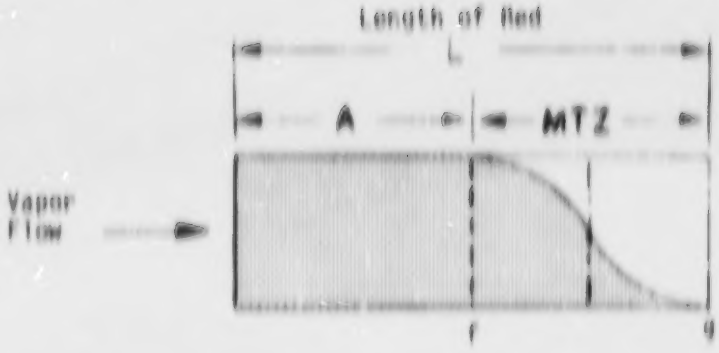


Figure 8
EFFECT OF CANISTER L/D RATIO ON WORKING CAPACITY



(example)

MTZ = 1/2 L

In zone "A" the carbon is fully saturated with hydrocarbons. In the Mass Transfer Zone (MTZ) a gradient condition exists as indicated by the curved line. The degree of saturation varies from fully saturated at "f" to fully available at "g" and averages about half utilized over the MTZ. The example bed would begin to exhibit breakthrough with any addition of vapor as points "f" and "g" would shift to the right and the bed would be about 75% utilized at that time.

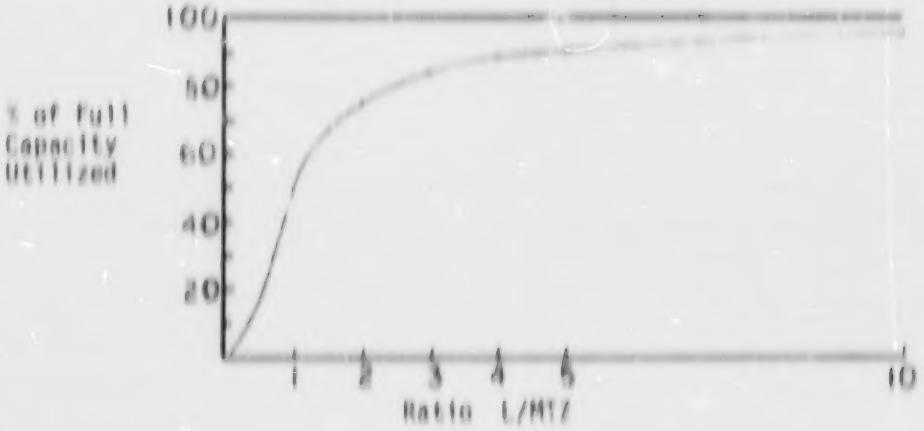


Figure 9

MASS TRANSFER ZONE CONCEPT

If one assumes a MTZ of about 6.6 cm in length for bed lengths of 13.3 and 26.6 cm, the longer bed would theoretically have about 12.5% more capacity at breakthrough than the shorter "baseline" canister. Actual test results indicated a working capacity 12.3% greater than "baseline" tests. Quadrupling the bed length over the "baseline" case of 13.3 cm would theoretically increase the working capacity 18.8% over the baseline case.

The above predictions are based on an absolute MTZ of 6.6 cm in length which should not change appreciably for a full size adsorber bed. Therefore, while the effect of the MTZ is important for short bed depths, a full size service station type system would be expected to be several feet deep and would be using greater than 95% of maximum capacity.

The fact that the H x 2A can had a slightly lower capacity than the "baseline" case is attributed to a potentially poorer distribution of vapors at the inlet which may have resulted in "channeling" through bed.

3.5 STRIP METHOD

Several practical methods to strip (remove) adsorbed hydrocarbon vapor from charged activated carbon were proposed. Working capacities of carbon stripped by the methods are discussed in the following sections.

3.5.1 Air Purge Flow Rates

Carbon was vapor-charged upward after which air was passed in the opposite direction downward through the carbon bed. Three different air purge flow rates were tested. Canister outlet gage pressure was regulated to zero ($\pm$1.5 in H_2O) during most of the strip when both air and high concentration vapor was issuing from the carbon bed. Only during the last moments of the strip, when air and low concentration vapors issue, did the pressure fall further to approximately -5.0 in. H_2O.

Working capacity of carbon stripped at three different flow rates is listed in Table 10 and shown graphically in Figure 10. The working capacity tended to diminish as air purge flow rate increased, however, the time to strip varied inversely with the flow rate indicating that approximately the same total volume of strip air was required for all three tests.

Table 10

PURGE RATE EFFECT ON WORKING CAPACITY

Test No.	Purge Rate cf/min	BVPM*	cm/sec	Purge Time min	Corrected Working Cap. gm/100 gm
(Baseline)	4000	9	2	12	6.03
2-4	20000	45	10	3	4.99
2-5	40000	90	20	1.5	5.21

*Bed volumes per minute

3.5.2 Stripping Temperature

Two carbons were charged with vapor from 9 psi and 14 psi RVP gasoline at 75°F in the normal manner after which heated purge air was used to strip the vapor from the carbon. Air temperature at the canister purge air inlet was recorded during each strip. Several minutes were required to achieve the required temperature during each strip. This temperature delay would be expected in a typical full size system to come on to temperature after an air heater was turned on.

Working capacity of two carbons for two gasoline vapors is listed in table 11. The results are presented in Figure 11. As indicated, there was no increase in working capacity by stripping with hot air. Although it was presumed that hot air stripping would significantly increase working capacity, two factors diminished the effect. First, the total BTU content of the heated air was low due to its low specific heat value compared to the specific heat and mass of carbon. This means that the 200°F air only contained enough heat to raise the carbon bed about 20-30°F during a 12 minute purge mode. The second factor was that the carbon bed did not cool down to ambient temperatures during the short one minute hold period prior to the subsequent charge mode and the slightly elevated temperatures during charge would tend to offset the slightly improved stripping ability of the hot air.

Increasing working capacity would require either much hotter air temperatures (low kindling point of some carbons would preclude very high air temperatures), heating of carbon directly such as with steam coils - resistance heaters - etc., and adopting a cooldown mode prior to successive charge modes. The feasibility of any of the above methods would involve comparing the gains in working capacity vs. the equipment cost, operating cost and energy consumption factors.

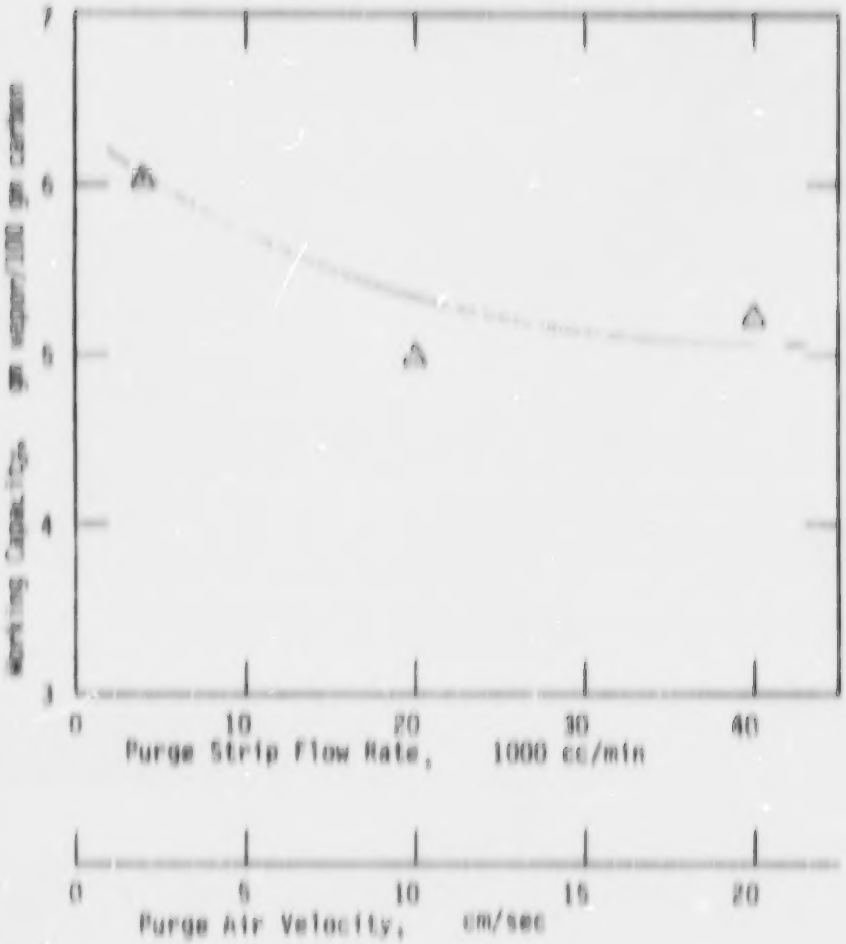


Figure 10
PURGE RATE EFFECT ON WORKING CAPACITY

Table 11
PURGE TEMPERATURE EFFECT ON WORKING CAPACITY

Test No.	Carbon Type	Nominal RVP %	Purge Air Temp. °F.	Corrected Working Cap. gm/100 gm
(Baseline)	W-1	9	75	6.03
4-3	W-1	9	150	6.40
4-15	W-1	9	150	6.49
4-4	W-1	9	200	5.82
4-16	W-1	9	200	5.10
1-5	X-1	9	75	5.49
4-11	X-1	9	75	5.62
4-12	X-1	9	150	4.87
4-13	X-1	9	200	5.65
4-5	W-1	14	75	6.69
4-6	W-1	14	150	6.44
4-7	X-1	14	75	6.52
4-8	X-1	14	150	6.45

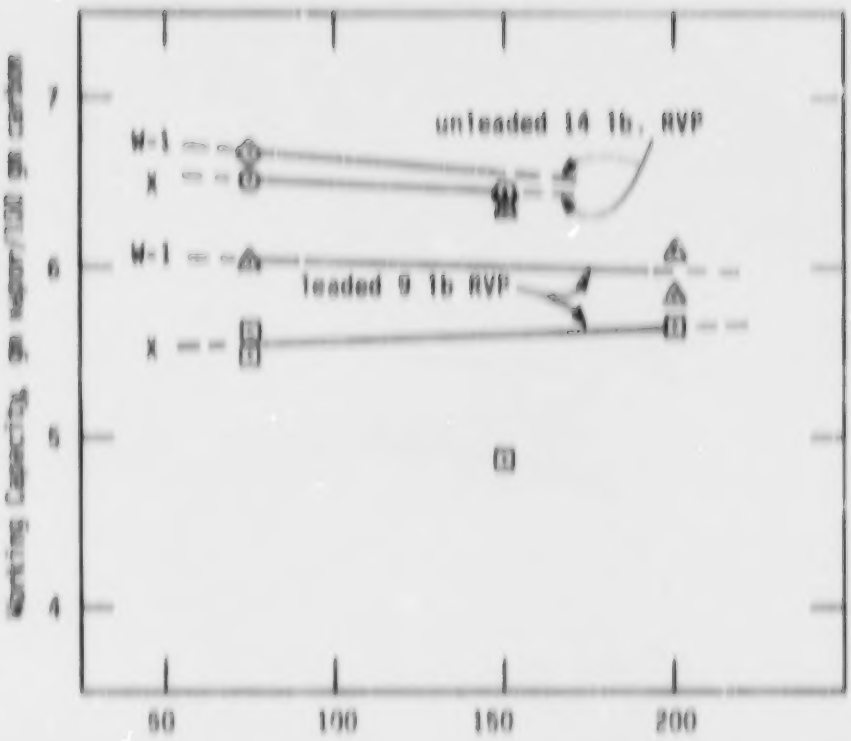


Figure 11
PURGE TEMPERATURE EFFECT ON WORKING CAPACITY

3.5.3 Relative Humidity

Relative humidity in the charge and strip air was controlled at three different levels to observe the effect on working capacity. Air was bubbled through water at regulated temperatures and pressures to establish 12, 40 and 80% relative humidity. See Table 12 for a summary of these conditions. Before testing, the carbon was acclimated to the moisture level in the air to be used for charge and strip. The data reported are grams of hydrocarbon adsorbed per 100 grams of carbon as acclimated to the moisture level tested. Working capacity as a function of relative humidity of the charge and strip air is presented in Figure 12. Working capacity is seen to diminish with increases in relative humidity.

Carbon adsorbs more moisture at higher humidity levels. The density of the carbon used in each test is also plotted on Figure 12. The relationship of working capacity to carbon density as discussed in Section 3.3.4 is upheld. Although it could not be determined accurately from three data points, the carbon working capacity is believed to vary with relative humidity as indicated by the dashed S-shaped curve.

3.5.4 Vacuum Stripping

Tests were performed to determine activated carbon working capacity using vacuum stripping techniques. Vacuum was regulated at two different absolute pressures--100 mm Hg and 25 mm Hg. No purge air flow was permitted during the vacuum strip operations. Therefore, no sample was available for analyzing hydrocarbon concentration to sense completion of strip. Instead the duration of the vacuum strip operation was timed to last approximately 8 1/2 minutes.

A one-minute delay was provided by the automatic control system after completion of vacuum strip before the start of the subsequent charge. Vacuum from the preceding strip was not totally lost in only one minute.

Table 12

RELATIVE HUMIDITY EFFECT ON WORKING CAPACITY

Test No.	Saturation Press. PSIA	Saturation Temp. °F.	Relative Humidity % @ 75° F.	Corrected Working Capacity gm/100 gm	W-1 Carbon Density As Tested gm/cc	W-1 Carbon % H_2O by Wt.
(Baseline)	32	36	12	6.03	0.380	2.5
1-15	14	49	40	4.95	0.411	10.0
1-16	14	69	80	4.68	0.452	18.1

Vacuum stripping did remove vapor from the carbon bed but with no air purge flow. A small quantity of vapor in the top of canister (isolated during vacuum strip) remained. The concentration of this vapor was reduced during vacuum strip but was still higher than the "charge breakthrough" setting. Consequently, each charge started into a partial vacuum and immediately drove out a slug of sufficiently high concentration vapor to signal the automatic control logic to terminate charge prematurely and skip on to the next strip mode. To overcome this problem, the "charge breakthrough" setting was raised to a higher concentration value. This allowed the charge mode to continue about 15 seconds longer than normal.

Working capacity of carbon stripped by vacuum is listed in Table13. The results of testing for the W-1 carbon are presented in Figure 13. Working capacity improves as absolute pressure during vacuum strip is reduced. Vacuum strip working capacities, at the pressures tested, are lower than air purge strip capacities. Extrapolation of these results indicates that vacuum stripping at an absolute pressure of 5 mm Hg may increase working capacity to be equal to comparable "air purge strip" working capacity.

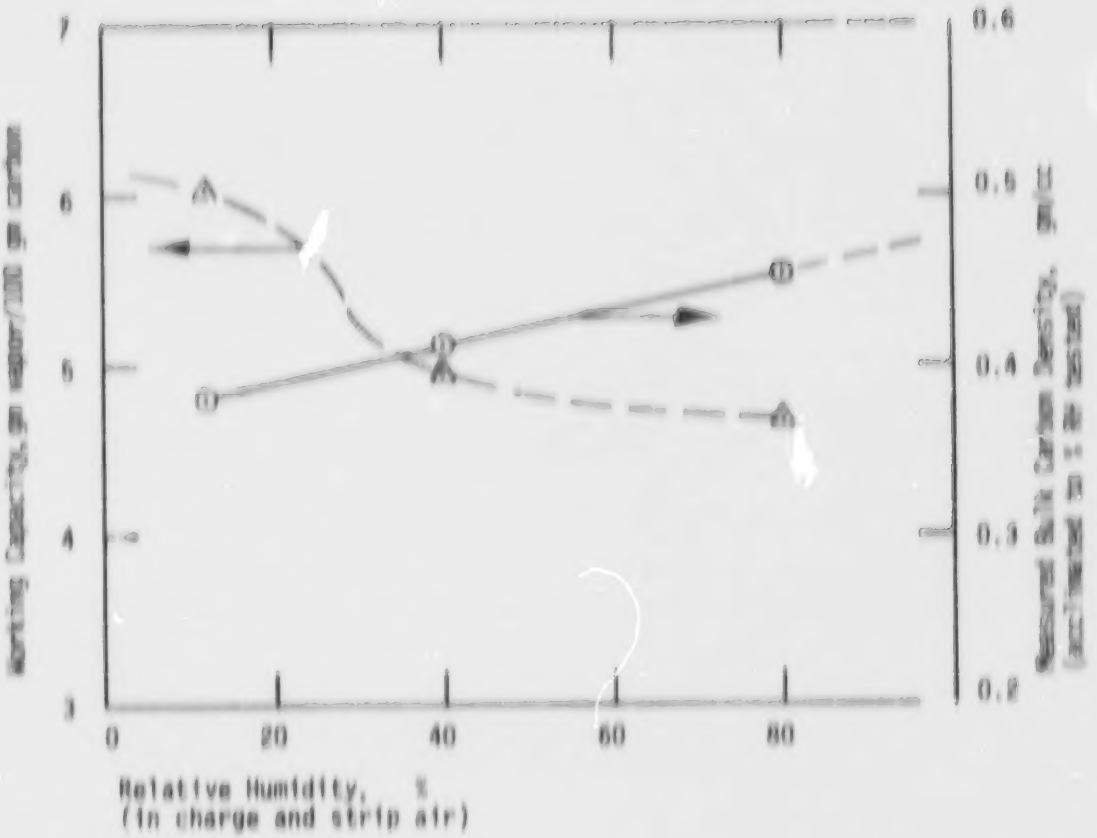


Figure 12
RELATIVE HUMIDITY EFFECT ON WORKING CAPACITY

Table 11

VACUUM STRIP EFFECTS ON WORKING CAPACITY

Test No.	Carbon Type	Nominal RVP lb.	Strip Press. mm Hg	Corrected Working Capacity gm/100 gm
3-2	W-1	9	100	0.33
3-3	W-1	9	100	1.40
3-4	W-1	9	25	3.90
3-4	W-1	9	25	4.05
3-4	W-1	9	25	3.90
3-4	W-1	9	25	4.42
3-16	X-1	9	25	3.46
3-16	X-1	9	25	3.80
3-16	X-1	9	25	4.18

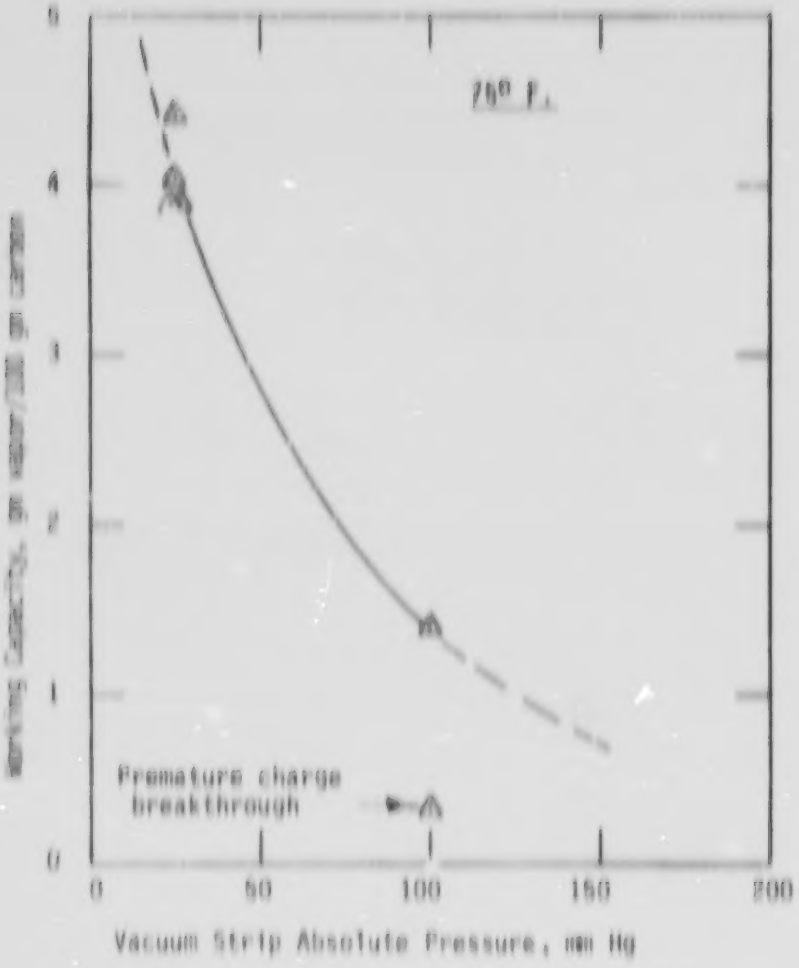


Figure 13
STRIP VACUUM EFFECT ON WORKING CAPACITY

Of particular concern for these vacuum stripping tests was the presence of a low concentration of hydrocarbons in the canister effluent during charge modes. This phenomenon is referred to as "bleedthrough" and was not evident with air purging. Bleedthrough hydrocarbon levels appeared to continuously increase with the number of operating cycles for both carbon types W-1 and X-1. Table 14 shows a comparison of bleedthrough levels.

Table 14

COMPARISON OF BLEEDTHROUGH LEVELS

Bleedthrough: hydrocarbon concentration expressed as volume % propane equivalent

Test No.	@ 4th Cycle	@ 10th Cycle	@ 20th Cycle
Baseline (air purge)	0.1%	0.1%	0.1%
3-2*	3%	5%	Too high to complete test
3-3*	3%	4%	5%
3-4*	1%	2%	3%

*See table 13for description of test conditions

Referring to test No. 3-4, one observes that the bleedthrough level is approximately 6% of the charge gas concentration of 50% C_3 and is increasing steadily. To achieve an overall control system efficiency of 90% only low levels of bleedthrough could be tolerated.

3.5.5 Hot Vacuum Stripping

Each of two carbons were charged with vapor from two gasolines after which the carbon beds were subjected to vacuum stripping at two elevated temperatures in an attempt to improve working capacity. All of the strips were performed at the better of the two absolute pressures (25 mm Hg) investigated in the previous section.

Hot vacuum strip cycles were not performed 21 time as in other tests. Instead, the carbon bed was first exercised through nine automatic charge and vacuum strips at 75° F. The test canister was then weighed, charged at 75° F.

and reweighed to determine the 75° F. working capacity. After placing the canister in a 150° F. oven for 15 minutes, the vacuum stripping commenced and continued for eight and one-half minutes (during which time the canister remained inside the oven). Immediately following the completion of the strip mode, the canister was weighed hot, allowed to cool at room temperature for 45 minutes, charged with 75° F. vapors and then reweighed. The difference in these previous two weight measurements was used to compute the working capacity for the 150° F. vacuum strip. The aforementioned steps were repeated this time using a 200° F. oven to determine working capacity for a 200° F. vacuum strip temperature.

Working capacities with vacuum stripping at three test temperatures are presented in Table 15 and are plotted in Figure 14. Strong improvement in working capacity is seen with rising vacuum strip temperature. The working capacity relation to gasoline volatility and carbon manufacturer is identifiable at all temperatures. Additionally, bleedthrough hydrocarbon levels decreased appreciably at the elevated temperatures within one or two operating cycles.

3.6 AMBIENT TEMPERATURE

The working capacity of carbon as affected by ambient temperature was investigated. One carbon was charged with the vapor from nine RVP gasoline after both the carbon and gasoline were stabilized at three different temperatures. Consequently, the results reflect not only the response of carbon to temperature but also to increases in the vapor pressure of the gasoline. (See Section 3.2)

Working capacity of carbon at different carbon/gasoline temperatures is listed in Table 16 and shown graphically in Figure 15. Working capacity increased with ambient temperature rise of both carbon and gasoline. The increase in vapor concentration of the same RVP gasoline with rising temperature is also shown.

Table 15

HEATED VACUUM STRIPPING VS WORKING CAPACITY

Test No.	Carbon Type	Nominal RVP lb.	Strip Press. mm Hg.	Strip Temp., °F	Corrected Working Capacity gm/100 gm
3-4	W-1	9	25	75	3.90
	W-1	9	25	75	4.06
	W-1	9	25	75	3.90
	W-1	9	25	75	4.42
3-11	W-1	9	25	150	5.33
	W-1	9	25	150	5.40
	W-1	9	25	150	6.09
3-12	W-1	9	25	200	6.58
	W-1	9	25	200	5.71
	W-1	9	25	200	7.05
3-6	W-1	14	25	75	5.42
	W-1	14	25	75	4.97
3-7	W-1	14	25	150	5.41
3-5	W-1	14	25	200	7.16
3-10	X-1	9	25	75	3.46
	X-1	9	25	75	3.80
	X-1	9	25	75	4.18
3-13	X-1	9	25	150	4.65
	X-1	9	25	150	5.58
	X-1	9	25	150	5.24
3-14	X-1	9	25	200	6.21
	X-1	9	25	200	7.08
	X-1	9	25	200	6.18
3-9	X-1	14	25	75	5.48
3-8	X-1	14	25	150	5.05
3-15	X-1	14	25	200	5.95

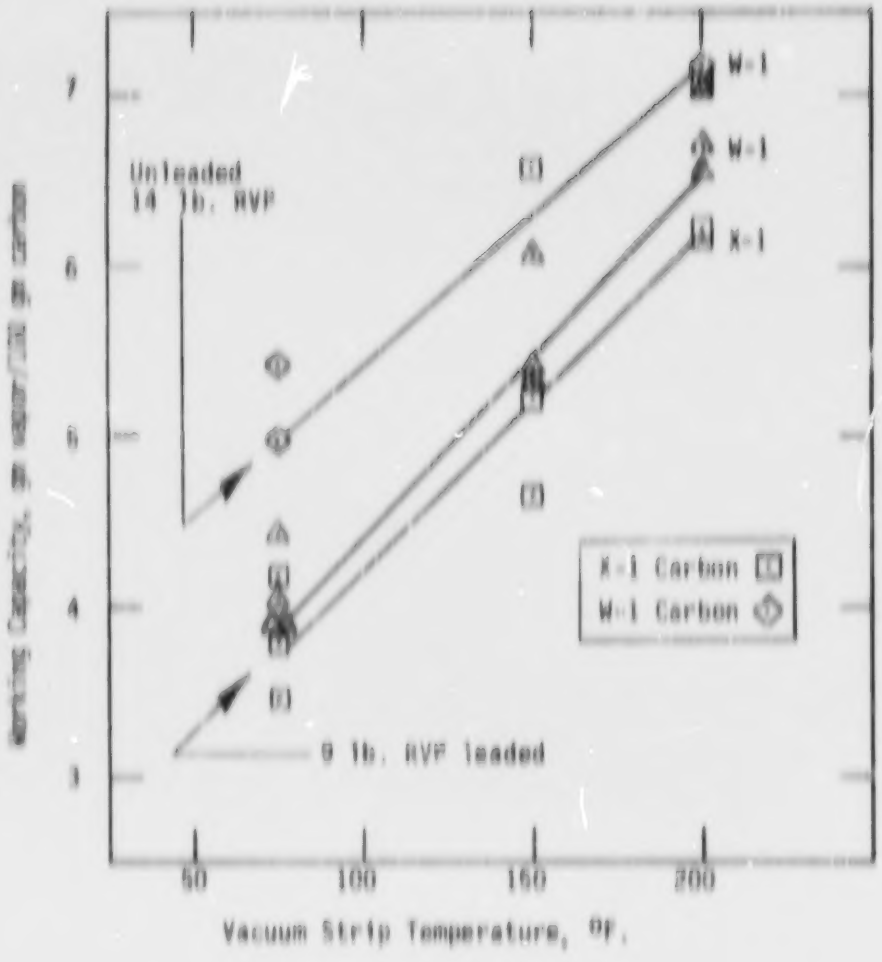


Figure 14
VACUUM STRIP TEMPERATURE EFFECT ON WORKING CAPACITY

Table 16
AMBIENT TEMPERATURE EFFECT ON WORKING CAPACITY

Test No.	Ambient Temp. °F.	Vapor Conc. Vol. %	Working Capacity gm/100 gm Observed	Working Capacity gm/100 gm Corrected*
1-13	50	32	4.97	5.70
(Baseline)	75	53.6	6.03	6.03
1-14	86	62	6.50	6.21

*Corrected to the Baseline vapor concentration of 53.6%

Working capacity at different carbon temperatures (gasoline temperature and volatility constant) was not investigated directly. But this information may be inferred by correcting these data to the baseline vapor concentration of 53.6% at 75° F. When these data are plotted on Figure 15, the lesser slope of the resulting line indicates the reduced effect of carbon temperature only on working capacity at constant volatility. The difference in slope between the "carbon temperature only" line and the "combined carbon gasoline temperature" line indicates the effect of "gasoline temperature only" on working capacity. This difference increases with vapor concentration and compares well with the results in Figure 1 in Section 3.2.

3.7 ONE THOUSAND CYCLE ENDURANCE TEST

The capacity of carbon to adsorb gasoline vapor during an extended period was investigated. After the standard 21-cycle test was completed on a canister, an additional 1000 cycles were performed. The apparatus was run continuously for 271 hours. Canister weight measurements were recorded approximately every 100 cycles. Vapor concentration in the generator was recorded periodically to account for weathering of the gasoline. Fresh gasoline was used twice to replace weathered gasoline.

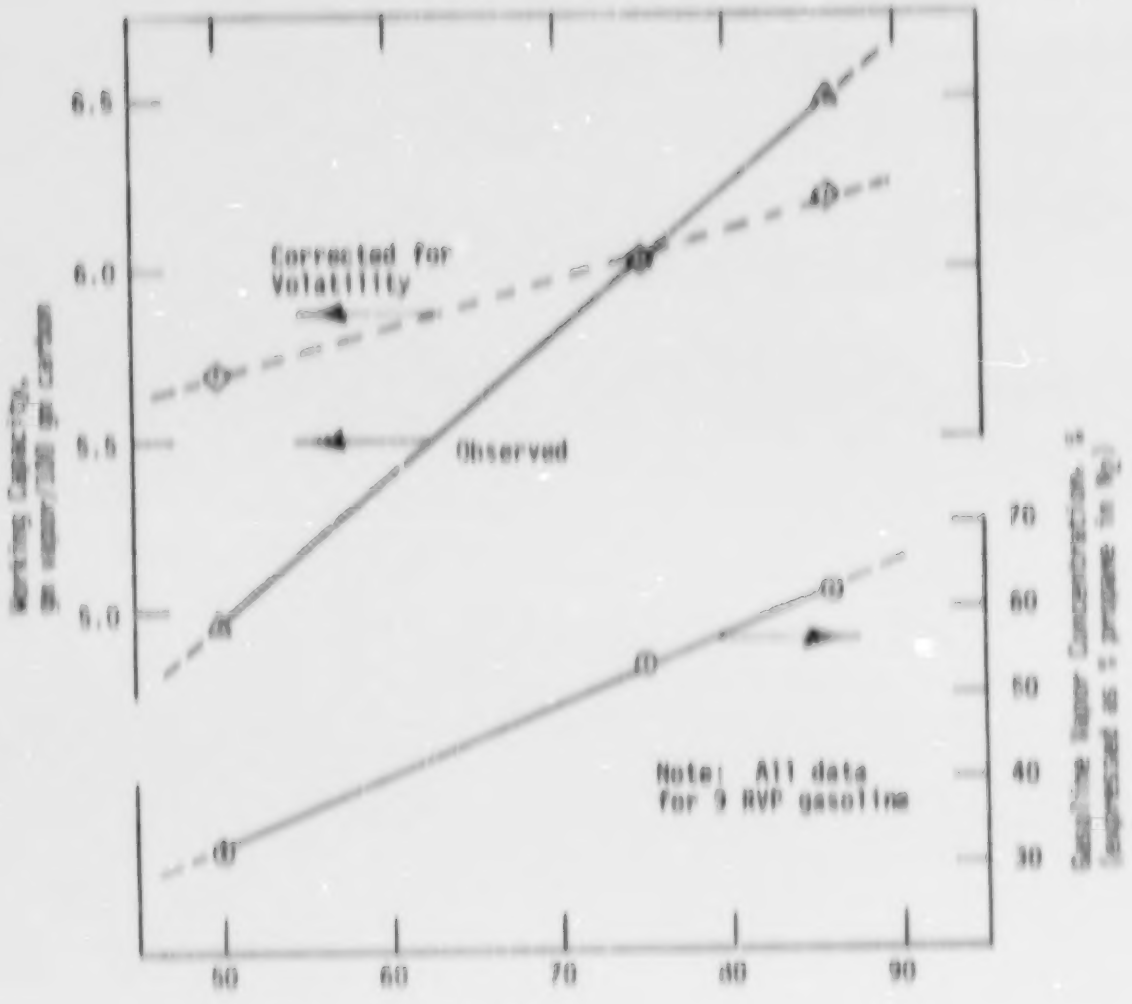


Figure 15
AMBIENT TEMPERATURE EFFECT ON WORKING CAPACITY

The combined canister, carbon and adsorbed vapor weight was recorded periodically after strip and after the succeeding charge. The tare weight of the canister and of the carbon bed were subtracted from these measurements to obtain the net adsorbed vapor weight. The remainders, the stripped heel and the total charged vapor weights are given in Table 17. The difference is working capacity which is also given.

These data are presented graphically in Figure 16. The top line is total charged vapor weight throughout 1023 cycles. The middle line is the heel weight. The bottom line is the difference between the upper two or working capacity. A decrease in working capacity of 29% occurred between the 21st and the 1023rd cycle. The heel is seen to increase throughout the test. Apparently, the carbon bed was accumulating more hydrocarbon molecules during each charge than were being removed during the subsequent strip with an attendant increase in weight. Total charged vapor weight is also seen to increase with cycles.

3.8 PRESATURATED CARBON

The working capacity of two carbons, W-1 and X-1, was determined after they had been presaturated with gasoline vapor. Each sample was continuously charged until there was no further weight gain. Then the samples were subjected to the normal test sequence except that the first charge was deleted. Working capacity for presaturated carbons is reported after 21 cycles the same as for normal tests. The data are assembled in Table 18. The total vapor weight, heel and working capacity are tabulated for both carbons.

Working capacity of presaturated carbon is presented in Figure 17. Neither presaturated carbon sample has as great a capacity as it has unsaturated. After 20 cycles the capacities were still rising and might have recovered their full capacities given more cycles. An additional eight cycles run on one sample showed working capacity was still being restored.

Table 17

WORKING CAPACITY AFTER EXTENDED CYCLES

Cycle	Date 1976	Uncorrected gm/100 gm Total Vapor	Heel	Working Capacity	Vapor Conc., Vol. %	Corrected Working Cap. gm/100 gm
1	9/2	12.94	0	12.94	50	13.06
2	9/2	15.81	8.59	7.22	50	7.34
3	9/2	17.41	10.97	6.44	50	6.56
10	9/2	18.22	12.22	6.00	50	6.12
21	9/2	19.44	13.38	6.06	50	6.18
100	9/4	21.22	15.44	5.78	53	5.80
200	9/5	22.34	16.50	5.84	52	5.89
291	9/6	23.47	18.16	5.31	52	5.36
388	9/7	24.09	18.91	5.18	51	5.27
462	9/8	24.38	19.19	5.19	50	5.31
633	9/10	24.91	19.84	5.07	57	4.95
725	9/11	24.94	20.06	4.88	56	4.80
823	9/12	25.03	20.28	4.75	54	4.74
948	9/13	25.03	20.38	4.65	53	4.67
1022	9/14	24.91	20.59	4.32	53	4.34
1023	9/14	25.09	20.72	4.37	53	4.39

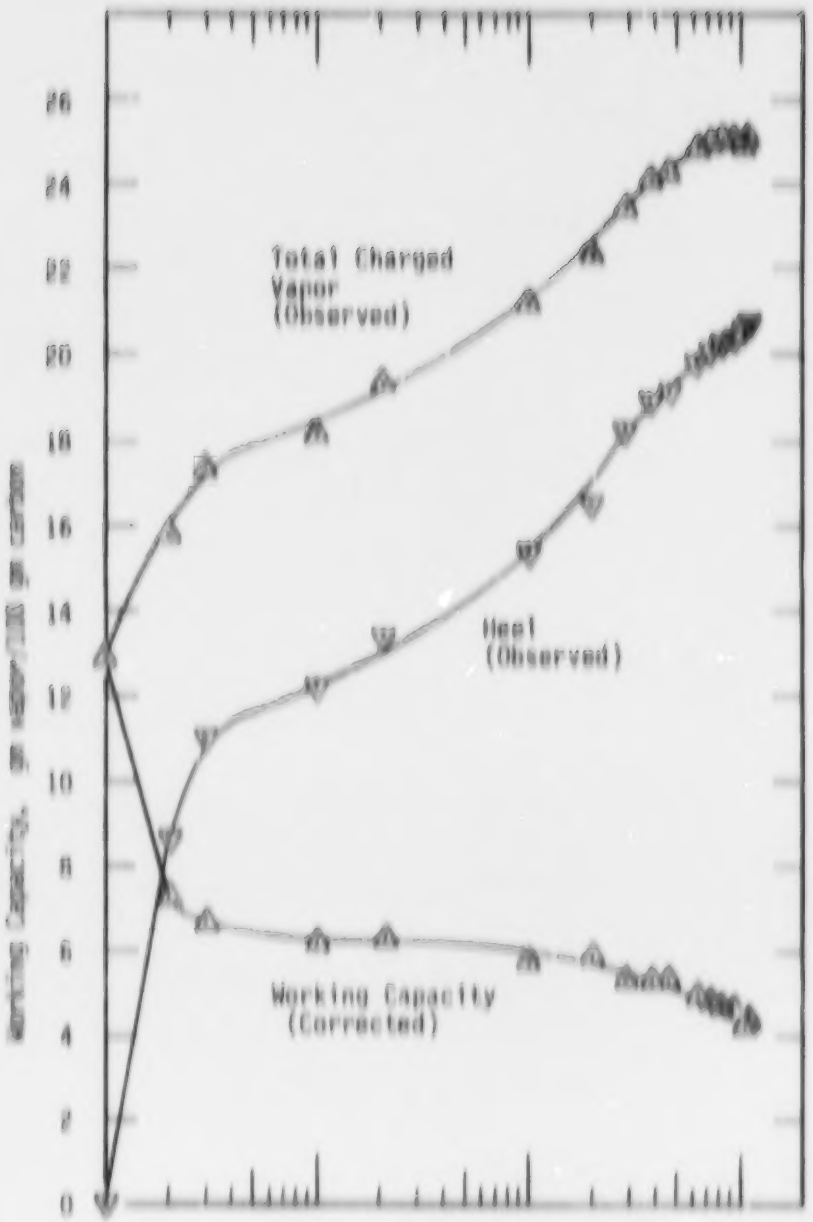


Figure 16
WORKING CAPACITY AFTER EXTENDED CYCLES

Table 18

SATURATED CARBON EFFECT ON WORKING CAPACITY

Cycle	Carbon Type	Uncorrected gm/100 gm Total Vapor	Heel	Working Capacity	Vapor Conc. Vol. %	Corrected Working Cap. gm/100 gm
1	W-1	30.84	30.94	0	53	0
2	W-1	29.78	26.16	3.63	53	3.65
3	W-1	29.16	25.34	3.81	53	3.83
12	W-1	27.66	23.38	4.28	53	4.30
21	W-1	27.19	22.63	4.56	53	4.58
29	W-1	27.03	22.25	4.78	53	4.80
1	X-1	34.60	34.60	0	50	0
2	X-1	32.98	30.23	2.75	50	2.87
3	X-1	32.60	29.54	3.06	50	3.18
10	X-1	31.30	28.04	3.26	50	3.38
21	X-1	30.70	27.16	3.54	50	3.66

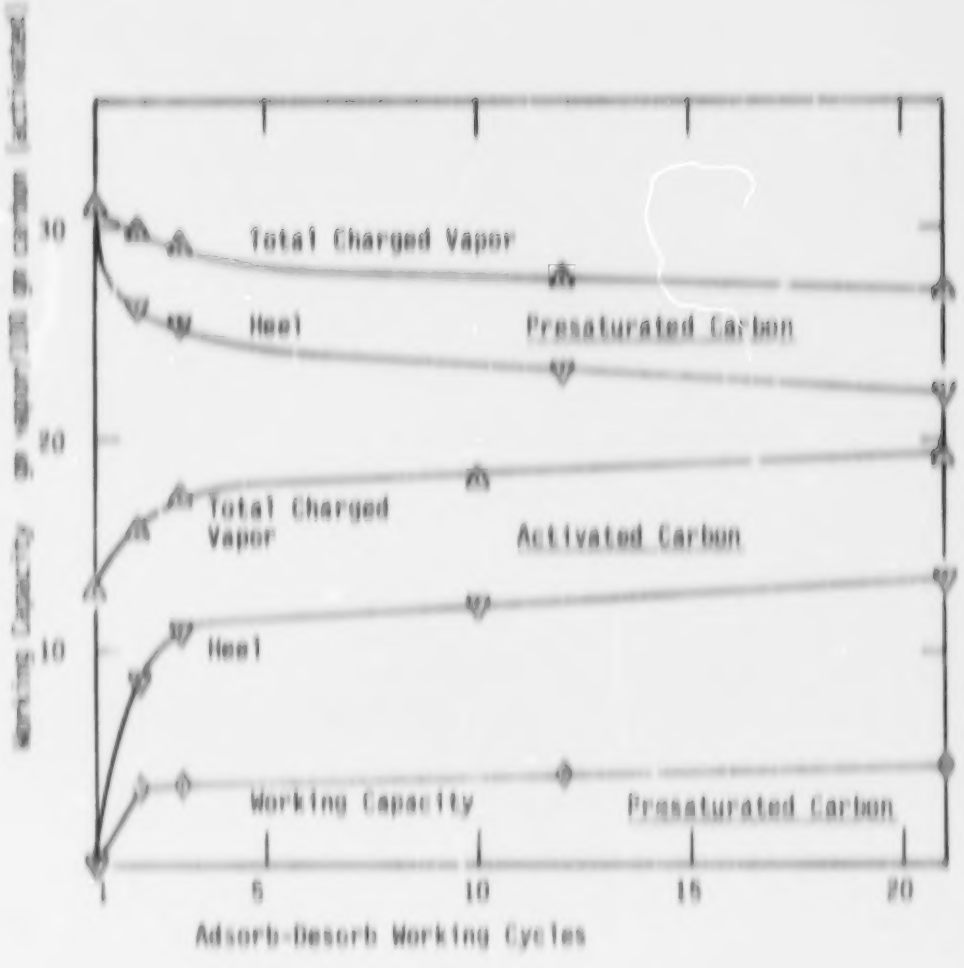


Figure 17
PRESATURATED CARBON EFFECT ON WORKING CAPACITY

3.9 SELECTIVE HYDROCARBON RETENTION

One of the program objectives was to determine if there was a tendency for the activated carbon to selectively retain certain hydrocarbons. Two approaches were used to (a) first determine the nature of the vapors which are retained on the carbon via comparison of the vapors entering the adsorber to the vapors being stripped, and (b) secondly determine the composition of the heel which accumulates in the carbon over a long time period.

3.9.1 Comparative Vapor Analyses

Syringe samples were taken of the gasoline vapors that were generated in the 55-gallon drums for analysis using gas chromatography (GC). Concurrently, bag samples were taken of the stripped vapors from various tests for analysis by the same method. The GC procedure separated the hydrocarbons esentially into five groups:

- C_2 (ethylene + ethane)
- C_3 (propylene + propane)
- C_4 (normal and iso-butane plus C_4 isomers)
- C_5 (normal and iso-pentane plus C_5 isomers)
- Heavy hydrocarbons (components with a boiling point above 40° C.)

Since C_2 and C_3 components are usually very minor, the area under the C_4 peak and the area under the heavy HC peak was used to provide a ratio of light to heavy hydrocarbons. If this ratio is higher in the stripped vapors than in the generator vapors, one might conclude that heavy HCs are being retained by the activated carbon and vice-versa.

Table 19 shows a summary of the analytical results where the ratio of C_4/heavy hydrocarbons entering the adsorber is denoted by "A", and the ratio of C_4/heavy hydrocarbons being stripped is designated "B". Values of B/A greater than 1.00 indicate a tendency to retain heavier hydrocarbons. All of the results pertain to 21-cycle tests except for the 1000-cycle test, 2-7/16. As shown, there are 12 out of 17 tests where the B/A is greater than unity indicating a tendency to retain heavy hydrocarbons and three out of 17 cases where a slight tendency to retain light hydrocarbons is indicated.

Table 19

GAS CHROMATOGRAPH ANALYSES OF VAPORS

Test No.	Description of Test		Ratio of Heavy Hydrocarbons A Vapors Entering Absorber	B Desorbed Vapors	B/A	Working Capacity gms/100 gms
1-1	Baseline*		.96	1.00	1.06	5.78
1-3	Y-1 Carbon		1.08	1.04	.96	11.40
1-8	Saturated 4-1 Carbon		.94	.94	1.00	4.56
1-9	4-7 Carbon		.94	1.02	1.08	4.47
1-10	4-5 Carbon		.87	.92	1.14	7.10
1-13	50 °F. Ambient		1.30	1.47	1.13	4.97
1-14	90 °F. Ambient		.95	1.04	1.09	6.50
2-5	40,000 cc/min strip		.61	.95	1.56	5.26
2-6	"Baseline"		.69	.65	.94	6.06
2-7/16	1000-cycle test # 435 cycles		.71	.71	1.00	5.19
	1000-cycle test # 907 cycles		.99	1.05	1.06	4.38
4-3	150° F. air strip	4-1 carbon	.79	.92	1.16	6.31
4-4	200° F. air strip	4-1 carbon	.72	.74	1.03	5.63
4-5	14 RVP fuel	4-1 carbon	2.59	3.02	1.17	6.69
4-6	14 RVP fuel & 150° air strip,	4-1 carbon	2.60	2.47	.95	6.34
4-8	14 RVP fuel & 150° air strip,	4-1 carbon	2.35	3.36	1.43	6.31
4-16	200° air strip,	4-1 carbon	1.06	1.64	1.55	6.28

* = Baseline conditions are 4-1 carbon, 12 x 28 mesh, 75° F. air strip at 4000 cc/min ambient temperature 75° F. 9 psi RVP fuel

Due to the inherent variability associated with the measurements and the extremely small amounts of heavy hydrocarbons retained each cycle, the extraction results discussed below are more enlightening.

3.9.2 Analysis of Extracted HC

A sample of activated carbon from the 1000-cycle test was desorbed using carbon disulfide. This mixture was injected into a chromatograph and analyzed by mass spectrometry. The results are shown on Table 20. Compared to a calculated heel before desorption of 171.4 milligrams/gram, the total desorbed weight of 175.7 milligrams per gram indicates that nearly all of the retained hydrocarbons were extracted and that they were primarily C_6 - C_9 components as shown on the table. The selective retention of molecules larger than C_6 is believed to be caused by the fact that these large molecules are firmly lodged in the micropore structure of the carbon and require higher energy levels to effect removal than do the smaller molecules. This would be especially true if the larger hydrocarbon molecules and the micropores are of comparable diameters.

Table 10

ANALYSIS OF HYDROCARBON HELD
FROM 1000-CYCLE TEST

	Milligrams Per Gram Charcoal
2-Methylpentane	1.12
3-Methylpentane	0.67
n-Hexane	1.19
2,4-Dimethylpentane	2.67
2-Methylhexane	8.47
n-Heptane	6.21
2,2,3-Trimethylbutane	45.88
2,5-Dimethylheptane	14.52
2,3,3-Trimethylpentane	8.64
Toluene & Methylethylheptane	35.11
2,2,5-Trimethylhexane	6.01
Methyloctane	5.57
2-Ethylheptane	7.30
3-Ethylheptane	3.01
m,p-Xylene	18.83
o-Xylene	4.06
Cumene	4.55
Methylethylbenzene	0.54
Ethyltoluene	2.55
1,2-Diethylbenzene	0.78
Total	172.68

4.0 TEST EQUIPMENT

4.1 TEST CHAMBER

All testing was conducted in Scott's environmental chamber in San Bernardino, California. This chamber is approximately 15 feet wide, 9 feet high and 35 feet long. The entire chamber is fully insulated and has temperature and humidity control. Temperature limits are -10° F. to 100° F. controllable to ±2° F. Humidity is controllable from ambient to 100 percent relative. Testing during the program was conducted at 50°, 75° and 90° F. The reason the environmental chamber was selected was due to the fact temperature affects the working capacity of carbon. By closely controlling the ambient temperature, variance was minimized.

4.2 AUTOMATIC TEST FIXTURE

Four individual carbon canister weighing stations were placed in the environmental test chamber. Vapor was delivered to each station by a gasoline vapor generator. Vapor breakthrough from each canister was sensed by non-dispersive infrared analyzers (NDIR). Automatic charge and strip modes were controlled by an electronic logic console. Vapor concentrations in the four generators were measured using one analyzer and a manually controlled four-way valve. The subsystems are described in the following sections. Figure 18 shows a flow diagram for the apparatus.

4.2.1 Hydrocarbon Instrumentation

Five NDIR (non-dispersive infrared) analyzers were assembled in a flow bench. One analyzer was connected to each of the four canister weighing stations and one was valved to analyze the headspace of any one of the four gasoline vapor generators.

The first four analyzers were adjusted to respond at full scale to approximately 40% propane (C_3H_8). The precise response curves were established with calibration gases of 2.05, 10.77 and 35.48% propane diluted with nitrogen (N_2). Propane calibration gases may not be mixed in air because of the hazard of explosion at the high pressures in gas cylinders. The instruments were zeroed using ambient air from the same compressor used to acclimate the charge and strip air.

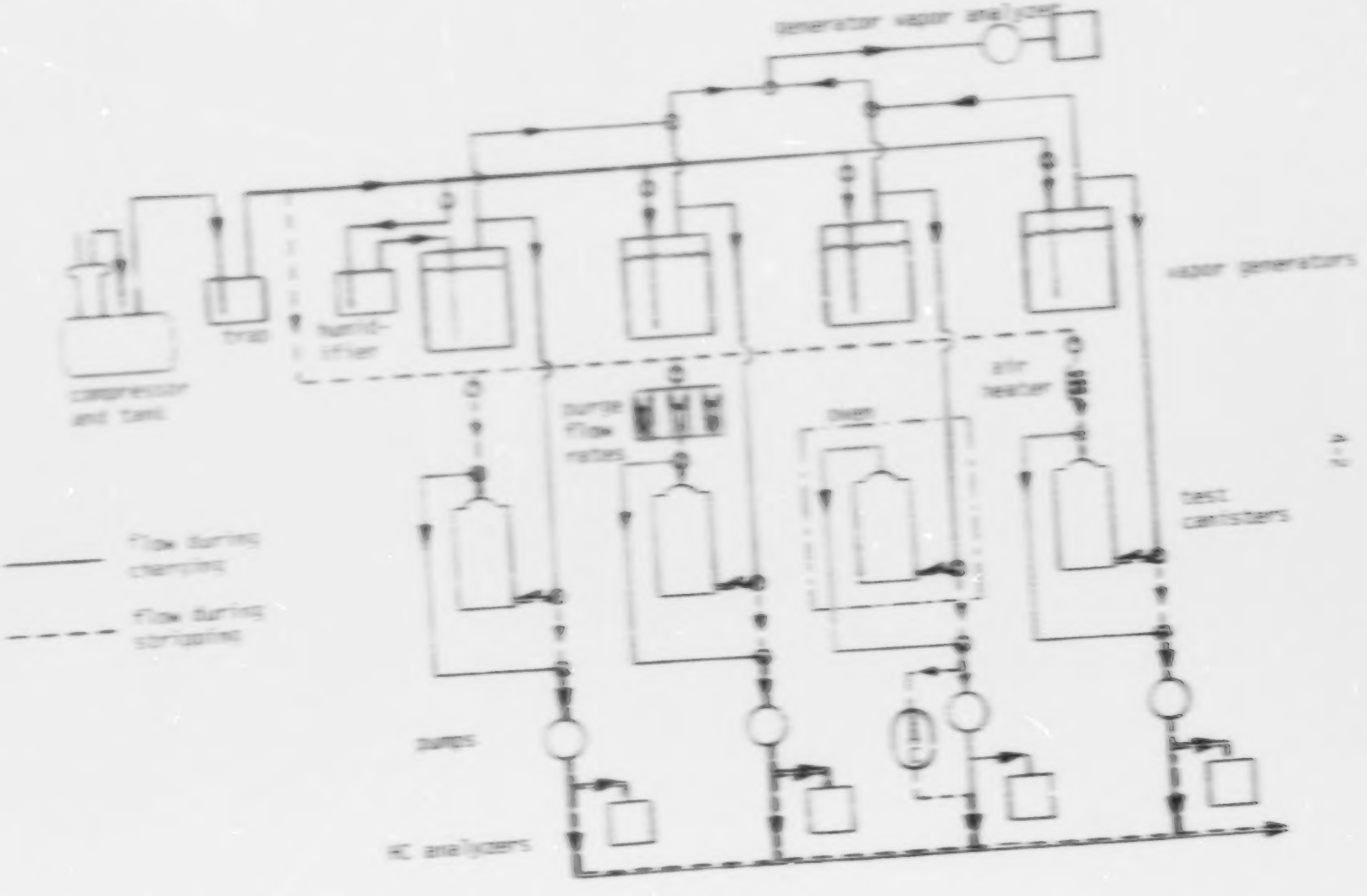


Figure 18

FLOW SCHEMATIC FOR TEST APPARATUS

Three solenoid valves were used to individually select which source of vapor would be analyzed. One valve carried charge breakthrough vapor from the top of the canister headspace to the analyzer. The second valve carried vapor-free air directly from the compressor to the analyzer during the one-minute duration hold period (between each charge and strip operation) so that the instrument was properly zeroed before each reading. A third valve allowed measuring vapor concentration at the bottom of the canister during the purge mode.

Oilless teflon coated diaphragm pumps were used to deliver the vapor to each HC analyzer. Flow was regulated by a needle valve and indicated by a rotameter. Analyzed vapor was directed to a large manifold vented to the roof. Pump capacity in excess of the flow required by the analyzer was bypassed through a backpressure regulator to the vent manifold. Total delivery delay time of the vapor from the canister to the analyzer was less than five seconds.

The fifth hydrocarbon analyzer was used to measure the concentration of vapor in the hydrocarbon generators. This analyzer was adjusted for full-scale response on 100% propane. The precise response curve was established with calibration gases of 18.77, 35.84, 66.5, 83 and 99.5% propane diluted with nitrogen. Zero response was set with air from the test chamber. Two manual and two electric valves were used to select which generator would be used to deliver vapor from the generators to the analyzer. The flow was regulated by a needle valve and indicated by a rotameter. After analysis the vapor was directed to the vent manifold.

4.2.2 Continuous Weighing Instrumentation

Four nearly identical canister weighing station were constructed. Each canister was supported by a load cell transducer. Weight increase during charge and weight decrease during strip were recorded on chart paper. The load cell was calibrated against known weights with the canister suspended in place so as to include the inherent spring rate of the interconnecting tubing. Under actual cyclic test conditions, the recorded weight traces were found to be extremely sensitive to pressure and temperature fluctuations. Manual weighing of test canisters was employed to monitor working capacity.

A tube introduced charge vapor/air mixture to the bottom of the canister. A circular perforated manifold distributed the vapor uniformly through a fiberglass wool pad which supported the carbon bed. The vapor flowed up through the bed and was adsorbed until the capacity of the carbon was exceeded at breakthrough. Charge effluent passed up through the bed and out through a tube in a rubber cork at the top of the canister.

The vapor was delivered by the regulated pressure in the vapor generator described in Section 4.2.4. Flow was governed by a solenoid valve, regulated by a needle valve and indicated by a rotameter. A backpressure regulator maintained atmospheric pressure inside the canister during charge. A pressure gage indicated canister head space pressure, and a thermocouple located approximately one-half inch beneath the top of the carbon bed was used to monitor bed temperature.

For purging strip air was introduced through the top tube to the head space of the canister and passed down through the carbon bed, desorbing vapor carrying it out through the glass wool, manifold and tube in the bottom of the canister. The strip air flow was pressure regulated, throttled by needle valve, indicated by rotameter, governed by solenoid valve and carried by the top tube to the head space of the canister. Another backpressure regulator maintained atmospheric pressure inside the canister during strip. The gage and thermocouple indicated as during charge.

Station #1 was modified to incorporate a second stage moisture control described in Section 4.2.5. Higher relative humidity was required for two experiments. Station #2 was modified to incorporate a high strip flow rate rotameter and large capacity pump to accommodate the high strip air flows required. Station #3 was modified to incorporate a vacuum pressure regulator and vacuum pump to perform the vacuum strip tests. An oven was set up next to this station in which hot vacuum strips were performed. Station #4 was modified to incorporate a strip air heater with which to perform the hot purge air strip tests.

4.2.3 Control Logic

The activated carbon test system was controlled by an electronic logic console. Internally divided into four independent channels, this console acquired the gasoline vapor concentration signal sensed by an NDIR analyzer from the outlet of each carbon canister during charge (top) or during strip

(bottom). Time delay relays were arranged to deliver power to the electric valves in each canister weighing test station. The electric valves were energized in a sequence required to deliver (charge) gasoline vapor to the carbon canister and remove (strip) vapor from the canister. The canister was isolated (hold) for one minute both before and after each charge during which the canister was available for weighing.

Vapor concentration limits were independently set to terminate charge and strip in each weighing station. Charge was terminated when vapor concentration emerging from the outlet (top) of the carbon bed exceeded (break through) the limit. Strip was terminated when the vapor concentration emerging from the outlet (bottom) of the carbon bed fell below the limit.

During vacuum strip tests no strip sample was available with which to sense HC concentration. A time delay relay was provided to control the period during which the canister was vacuum stripped.

An array of color coded light emitting diodes was provided for each canister weighing test station. The performing mode in the test cycle was indicated for each canister. Overriding toggle switches were provided for manual operation of the system. A cycle counter was provided for each canister. A rotary switch was provided with which to select one of four gasoline vapor generators to analyze. The vapor generator analyzer and recorder were controlled from the logic console. The individual canister weight transducers were calibrated with controls in the logic console. Zero, coarse and fine trim potentiometers were provided.

4.2.4 Hydrocarbon Vapor Generator

Four hydrocarbon vapor generators were constructed--one for each carbon canister weighing station. The 55-gallon barrel in which the gasoline was received was modified to generate vapor. A sintered metal bubbler was installed through the ¾" bung and was submerged near the bottom. Pressurized, moisture controlled air was delivered from the compressor to the bubbler. An individual pressure regulator was provided for each generator and a solenoid valve governed air flow during charge only. Check valves protect the solenoid valve and regulator from reverse flow of gasoline in the event of lost pressure.

A multiport standpipe was screwed into the two-inch bung opening. Five pipe taps were provided in the standpipe. One led to a pressure gage near the pressure regulator which supplied the bubbler. Pressure was maintained constant and as low as possible (4 - 6" H_2O). The second tap carried charge vapor to the canister weighing station described in Section 4.2.2. A third tap carried generated vapor, when selected, to an NDIR hydrocarbon analyzer described in Section 4.2.1. Selection is made only during charge so that the analysis is representative of the vapor being adsorbed by the carbon. A fourth tap led to a pressure relief vent valve to protect the barrel from rupture in case of overpressure. The fifth tap led to a normally open solenoid valve which opened to vent the barrel whenever the air compressor electrical power was lost or turned off. This feature provided further safety (as during a weekend shutdown) by preventing thermal pressure buildup and possible rupture or overflow of gasoline from the barrel.

The gasoline barrels were placed in the temperature controlled test chamber several days before testing so that the liquid temperature and vapor concentration could be stabilized.

4.2.6 Moisture Controlled Air Compressor

The necessity to control the percent of moisture in the carbon for experimental purposes was made evident by the inconsistency between the adsorption characteristics of wet and dry carbon. With each succeeding charge cycle, dry carbon exhibited an even higher total weight. Succeeding heels increased but at a lesser rate which resulted in an increasing working capacity between total and heel. Wet carbon displayed little or no increase in total adsorbed vapor, heel or working capacity after the first charge. All three weights were less than for dry carbon after several cycles.

For consistency in experimental results, it was decided that all measurements should reflect only the increase or decrease of hydrocarbon vapor. Therefore, the moisture content of the carbon had to be acclimated to the moisture content of the charge and strip air. For consistency throughout the program, the moisture content of the air had to be constant.

A moisture controlled air compressor system was assembled and located in a room adjacent to the test chamber both to remove the compressor noise and to prevent ingestion of possible background vapor

A large capacity oilless diaphragm pump was mounted on a pressure tank. A moisture condensing trap in a refrigerated water bath was mounted next to the pump.

The thermostat on the water bath was set at 36° F.--as cold as possible without freezing the water. A pressure switch controlled tank pressure between 12 and 24 psig. Moisture in the air leaving the tank condensed in the trap. The air exited the trap saturated with moisture at an average of 18 psig. Saturation at this pressure and temperature determines that the specific humidity is 14.7 grains H_2O/lb. dry air. This moisture level results in a relative humidity of 12% at the test conditions of 75° F. and 0 psig. All carbon types were acclimated with this air to either add or remove moisture until equilibrium was observed in stabilized total carbon weight.

For those tests where higher relative humidity was required, an additional temperature controlled water bath was installed. Two water filled bubblers were placed in the bath. One provided moisture to the charge air just before it entered the vapor generator. The other bubbler provided moisture to the strip air just before it entered the canister. The bath temperatures surrounding the bubblers was set at 49° F. for 40% relative humidity air and 69° F. for 80% relative humidity.

4.2.6 Carbon Bed Canister

The can commonly used for aerosol sprays was selected for carbon bed evaluation. This can was able to withstand the vacuum pressures involved in this program. The spray valve disc was removed from the top to expose a hole large enough to pour in the carbon. A 3/8" diameter tube manifold was soldered in the side of the can with one leg sticking out. The manifold was formed in a circle with distribution holes around the inside bottom of the can. Struts were added to strengthen the leg of the tube sticking out. A one hole rubber cork with a 3/8" diameter tube was placed in the top of the can.

A fiberglass wool pad, 1/4" thick, was placed on top of the circular manifold to support the carbon bed. A ball of glass fiber was stuffed inside both of the 3/8" tubes at the top and bottom of the canister to prevent escape of the carbon particles.

The effective volume of this canister was 440 cc. Two sets of canisters were made so that one set could be tested while the other set was being loaded. Two additional cans were fabricated for investigation of different canister configurations. One had twice the length of the standard can but equal diameter. The other had twice the cross sectional area ($\sqrt{2}$ x diameter) as the standard can but equal length.

APPENDIX A

Correspondence

Form Letter

Scott Environmental Technology has been awarded a contract by the Environmental Protection Agency to evaluate the properties of activated carbon in conjunction with gasoline vapor emission control at service stations. A literature search revealed that your company was a supplier of activated carbon.

The purpose of this letter is to solicit available information about activated carbon. It would be greatly appreciated if you would fill out and return the attached questionnaire as well as forward any information you have regarding your activated carbon product. All data submitted will become the property of the EPA and will eventually be made public.

Thank you for your time and effort spent responding.

Sincerely,

Michael J. Manos
Project Manager
Environmental Services Department

sd
Attachment

Attachment

ACTIVATED CARBON QUESTIONNAIRE

Company _____

Do you presently manufacture activated carbon? Yes____ No____

Are you presently a supplier of activated carbon? Yes____ No____

If you are only a supplier, who manufactures the activated carbon?

Company _____

Address _____

_____

Phone _____

Do you supply an activated carbon suitable for hydrocarbon adsorption and desorption? Yes____ No____

Identification No. _____

Type Carbon _____

Is this activated carbon used to control service station hydrocarbon emissions? Yes ___ No____

If yes, where? _____

* *

Do you regenerate activated carbon? Yes____ No____

If yes, method used _____

* *

Do you manufacture or supply a service station hydrocarbon emission control system? Yes____ No____

If yes, briefly describe: _____

_____

_____

Name and phone number of individual in your company to contact if additional questions arise.

Name _____

Phone No. _____

P.O. Box 2526
Columbus, Ohio 43216

RECEIVE
JAN 2 9 19

Scott Environmental Techn

Attachment

ACTIVATED CARBON QUESTIONNAIRE

Company Barnebey-Cheney

Do you presently manufacture activated carbon? Yes X No

Are you presently a supplier of activated carbon? Yes X No

If you are only a supplier, who manufactures the activated carbon?

Company

Address

Phone

Do you supply an activated carbon suitable for hydrocarbon adsorption and desorption? Yes X No

Identification No. Type AC & Type VG

Type Carbon Coconut shell

Is this activated carbon used to control service station hydrocarbon emissions? Yes No X

If yes, where?

Do you regenerate activated carbon? Yes X No

If yes, method used Combination thermal and steam regeneration

Do you manufacture or supply a service station hydrocarbon emission control system? Yes No X

If yes, briefly describe: However, we manufacture several different panel and canister adsorbers which could be used effectively

Name and phone number of individual in your company to contact if additional questions arise.

Name Gary V. Hartman

Phone No. 614 258-9501

Attachments: Charcoal literature package; T-74, 264, 142

Under separate cover: 1-lb each Types AC and VG Charcoals

CALGON
SUBSIDIARY OF MERCK & CO. INC.

A-4

RECEIVED
FEB 13 1976
Scott Environmental Technology

ACTIVATED CARBON DIVISION CALGON CORPORATION CALGON CENTER BOX 1346 PITTSBURGH, PA. 15230 (412) 923-2345

February 10, 1976

Mr. Michael Manos
Scott Environmental Technology
2600 Cajon Boulevard,
San Bernardino, California 92411

Dear Mr. Manos:

Confirming our recent telephone conversation, we are sending you a 5 gallon sample of BPX 8 x 30 which is suitable for the recovery of gasoline vapors at service stations.

Enclosed you will find with the questionnaire which you recently sent a report which summarizes information gathered during our investigation programs in regard to:

a) Carbon systems efficiency.

b) Activated carbon working capacity.

c) Working capacity and life with air sweep regeneration.

d) Working capacity and life with vacuum regeneration.

e) Heat characteristics.

We are confident that this report will be of interest to you.

We hope that our data and commentary are useful. Please advise if there are any questions or additional ways in which we may assist.

Very truly yours,

R. L. Grandjacques
Development Engineer

RLG:rmk

Enclosure

cc: Mr. R. L. Cooley

Attachment

ACTIVATED CARBON QUESTIONNAIRE

Company Calgon Corporation

Do you presently manufacture activated carbon? Yes X No ____

Are you presently a supplier of activated carbon? Yes X No ____

If you are only a supplier, who manufactures the activated carbon?

Company ____

Address ____

Phone ____

Do you supply an activated carbon suitable for hydrocarbon adsorption and desorption? Yes X No ____

Identification No. BPX

Type Carbon BX30

Is this activated carbon used to control service station hydrocarbon emissions? Yes X No ____

If yes, where? In San Diego County. Our carbon is used by three equipment manufacturers.

Do you regenerate activated carbon? Yes X No ____

If yes, method used thermally

Do you manufacture or supply a service station hydrocarbon emission control system? Yes ____ No X

If yes, briefly describe: ____

Name and phone number of individual in your company to contact if additional questions arise:

Name Bernard Grandjacques

Phone No. 412-923-2341

ICI United States Inc.

WILMINGTON, DELAWARE 19897
(302) 658 9311

(302) 575 - 4353

RECEIVED

FEB - 5 1976

Scott Environmental Technology

February 3, 1976

Mr. Michael J. Manos
Environmental Services Department
Scott Environmental Technology Inc.
2600 Cajon Blvd.
San Bernardino, CA 92411

Dear Mr. Manos:

Under separate cover I have sent you a 5 gallon pail containing 12x30 mesh Granular DARCO. Enclosed you will find product literature and a bulletin discussing activated carbon and the adsorption process in detail.

The pore structure of Granular DARCO is larger on the average than vapor phase carbon. As a result, while adsorption of high vapor pressure compounds will be less, desorption will occur at lower temperatures. As higher boiling gasoline components are adsorbed by activated carbon, adsorption of lower boiling compounds will decrease. This decrease will be less with Granular DARCO than conventional vapor phase carbons. Considering the significantly lower cost of Granular DARCO on a volume basis, I think its working capacity as service carbon will be at least as good on a cost performance basis. Because of the pore distribution of Granular DARCO, it will be possible to drive off adsorbed hydrocarbons at lower temperatures than carbons with a finer pore structure. This could simplify desorption and make on-site regeneration more feasible.

We appreciate the opportunity of working with you. If we can be of further assistance, please contact me. Thank you for your interest in DARCO carbons.

Very truly yours,

John R. Conlisk

John R. Conlisk
Laboratory Supervisor
Product Development Department

JRC/pal
069

Attachment

ACTIVATED CARBON QUESTIONNAIRE

Company Calgon Carbon Corp.

Do you presently manufacture activated carbon? Yes ✓ No ___

Are you presently a supplier of activated carbon? Yes ✓ No ___

If you are only a supplier, who manufactures the activated carbon?

Company ___

Address ___

Phone ___

Do you supply an activated carbon suitable for hydrocarbon adsorption and desorption? Yes ✓ No ___

Identification No. ___

Type Carbon Vapor Phase Granular

Is this activated carbon used to control service station hydrocarbon emissions? Yes ___ No ✓

If yes, where? ___

Do you regenerate activated carbon? Yes ___ No ✓

If yes, method used ___

Do you manufacture or supply a service station hydrocarbon emission control system? Yes ___ No ✓

If yes, briefly describe: ___

Name and phone number of individual in your company to contact if additional questions arise:

Name John R Crabtree

Phone No. 412 787 5554

A-8

UNION CARBIDE CORPORATION

CARBON PRODUCTS DIVISION

39 OLIVER AVENUE, CLEVELAND, OHIO 44107 : TELEPHONE: 216 [illegible]

ADDRESS REPLY TO
P. O. BOX 5687
CLEVELAND, OHIO 44101

February 10, 1976

Mr. Richard J. Nimmo
Scott Environmental Technology Inc.
2600 Cajon Blvd.
San Bernadino, California 92411

RECEIVED
FEB 18 1976
Scott Environmental Technology

Dear Mr. Nimmo:

In your activated carbon questionnaire attached to your January 20, 1976, you asked for the type of activated carbons used for hydrocarbon adsorption.

We have manufactured and supplied, over the last 35 years, 70-90% of the activated carbons for adsorption and recovery of hydrocarbons from gas streams before these gas streams entered the atmosphere. Examples of the processes using adsorption to clean the process air include rotogravure, lithographic, film casting, and rayon.

The type of carbon used will depend on such parameters as adsorptive capacity required, pressure capability of the gas pump system, and expected life of the activated carbon.

We have supplied the activated carbon for a majority of the manufacturers of gasoline vapor adsorption equipment. The type carbon required has not been established.

The following "Columbia" activated carbon grades have been evaluated and were all found to be successful:

Coal base:	HBV 6/8 , HBV 8/10
Petroleum base:	JXC 6/8, JXC 4/6

Nutshell carbons would also be suitable for the adsorption of the hydrocarbon emissions.

I am enclosing information on our "Columbia" activated carbons. If you have any questions, or if we can be of further help, please let us know.

Very truly yours,

Blaine R. Joyce

Blaine R. Joyce
Technical Service
Activated Carbon Products

BRJ/rdf
Enc.

Attachment

ACTIVATED CARBON QUESTIONNAIRE

Company Union Carbide Corporation

Do you presently manufacture activated carbon? Yes X No____

Are you presently a supplier of activated carbon? Yes X No____

If you are only a supplier, who manufactures the activated carbon?

Company____

Address____

Phone____

Do you supply an activated carbon suitable for hydrocarbon adsorption and desorption? Yes X No____

Identification No.____

Type Carbon See attached

Is this activated carbon used to control service station hydrocarbon emissions? See attached Yes____ No____

If yes, where? See Attached

Do you regenerate activated carbon? Yes X No____

If yes, method used Thermal

Do you manufacture or supply a service station hydrocarbon emission control system? Yes____ No X

If yes, briefly describe:

Name and phone number of individual in your company to contact if additional questions arise.

Name Allan Koppel

Phone No. (312) 654-2000 : Ext. 2102

RECEIVED
FEB - 9 1976
Scott Environmental Technology

Westvaco

January 27, 1976

Mr. Michael J. Manos
Scott Environmental Technology
Environmental Services Department
2600 Cajon Boulevard
San Bernadino, California 92411

Dear Mr. Manos:

In reference to your letter dated January 20, I have enclosed the completed questionnaire and would like to take a minute now to review Westvaco's achievements in the vapor emission control area.

Please check back in your records for my letter to Mr. Dyrle Quick dated September 26, 1975. This letter contained several enclosures outlining the various patent work performed by Westvaco in the early 1970's.

Most of the design concepts in the vapor control field were developed by Don Tolles at our Charleston Research Laboratory. Don's work included the following:

1. "Methods of Controlling Hydrocarbon Vapor Emissions From Fuel Storage Tanks"

2. "Adsorber Designs Especially Suited for Applications Involving Regeneration by Evacuation or Low Temperature Purge"

3. "Regeneration Process for Adsorbents and Disposal of Recovered Vapors"

4. "Adsorption and Regeneration Method Using Annular Cartridge Adsorption Elements"

5. "Control of Refueling Losses Using Activated Carbon Adsorption" - Canister design and laboratory performance testing of a refueling vapor emission control suitcase-type adsorber, fully portable

Chemical Division
Carbon Department
Covington, Virginia 24426
Telephone: 703 962-2111

6. Technical assistance in the development of the RBW/Takheim System.

Most of the reports and prototype information are currently not available for out-of-company distribution and are listed as "confidential." Release of portions of this data could be arranged under a nondisclosure agreement. However, please note that some sections of these reports were copied and sent to Mr. Dyrie Quick on September 26, 1975.

Westvaco can provide suitable prototype design, including the fabrication of an experimental test unit along with the normal complement of engineering consulting. Anything larger than the initial pilot units would probably have to be subcontracted out, but we would like a chance to review that design before declining.

Westvaco has been very active in refueling emission control applications; we have the talent and the capability and would certainly appreciate the chance to get involved once more. Samples of our products can be sent upon request. Product data information on our wood-based WV-A can be sent upon request.

Read over the enclosed literature and product data bulletins and let us know what else we can do to help out.

Sincerely yours,

Edward G. Pollta

Edward G. Pollta
Environmental Services Engineer

EGP/ckj

Enclosures

Attachment

ACTIVATED CARBON QUESTIONNAIRE

Company Westvaco

Do you presently manufacture activated carbon? Yes ___ No___

Are you presently a supplier of activated carbon? Yes X No___

If you are only a supplier, who manufactures the activated carbon?

Company ___

Address ___

___

Phone ___

Do you supply an activated carbon suitable for hydrocarbon adsorption and desorption? Yes X No___

Identification No. WV-H and/or WV-A

Type Carbon bituminous coal/wood based

Is this activated carbon used to control service station hydrocarbon emissions? Yes X No___

If yes, where? Westvaco wood-based WV-A, 14x35, and coal-based, 8x30, used in automotive industry in evaporative fuel canisters

Do you regenerate activated carbon? Yes___ No X

If yes, method used ___

Do you manufacture or supply a service station hydrocarbon emission control system? Yes___ No X

If yes, briefly describe: Note: However, we do produce activated carbon suitable for such units ___

___

Name and phone number of individual in your company to contact if additional questions arise.

Name Edward G. Polity, Environmental Services (

Phone No. (703) 962-6081

Witco Chemical

RECEIVED
JAN 29 1976
Scott Environmental Technology

January 27, 1976

Mr. Michael J. Manos
Project Manager
Environmental Services Dept.
Scott Environmental Technology Inc.
260 Cajon Blvd.
San Bernardino, California 92411

Dear Mr. Manos:

Enclosed, please find the completed questionnaire sent to Witco in your letter of January 20, 1976.

Please feel free to telephone or write me for any additional data your program may require.

Very truly yours,

E. M. Saffer, Jr.
Technical Director
Tel: 212-544-6438

EMS:ll
enclosure

Attachment

ACTIVATED CARBON QUESTIONNAIRE

Company Witco Chemical Corp.

Do you presently manufacture activated carbon? Yes X No___

Are you presently a supplier of activated carbon? Yes X No___

If you are only a supplier, who manufactures the activated carbon?

Company_____

Address_____

_____

Phone_____

Do you supply an activated carbon suitable for hydrocarbon adsorption and desorption? Yes X No___

Identification No. Grade 950

Type Carbon Bold Granular

Could be

Is this activated carbon used to control service station hydrocarbon emissions? Yes X No___

If yes, where?_____

Do you regenerate activated carbon? Yes___ No X

If yes, method used _____

Do you manufacture or supply a service station hydrocarbon emission control system? Yes___ No X

If yes, briefly describe:_____

_____

_____

Name and phone number of individual in your company to contact if additional questions arise:

Name Charles H. Saffer, Jr.

Phone No. 212-644-6438

CALGON
SUBSIDIARY OF MERCK & CO., INC.

ACTIVATED CARBON DIVISION · CALGON CORPORATION · CALGON CENTER · BOX 1346 · PITTSBURGH, PA 15230 · (412) 921-2345

RECEIVED
JUN 1 1976
Scott Environmental Technology

May 25, 1976

Mr. Michael Manos
Scott Environmental Technology
2600 Cajon Blvd.,
San Bernardino, California 92411

Dear Mike:

It was a pleasure to meet you and Bob and to discuss the application of granular carbon in gasoline vapor recovery. Following our conversation, I have consulted our Research staff to determine what method they use for the determination of hydrocarbon heels. They use the two following methods:

1. The carbon disulfide technique

   The sample is Soxhlet extracted for 16 hours; the carbon disulfide evaporates at room temperature; the sample then is injected in the chromatograph. Our Research staff which has a lot of experience with the extraction technique prefers to use carbon disulfide which they found to be the best solvent for the operation. Other solvents can also be used. The method is mostly used with samples which contain compounds liquid at room temperature.

2. Solid sample injection technique

   This method is used in particular with samples which contain low boilers. It requires the right GLC equipment.

Enclosed you will find the isotherm data of the most common aliphatic and aromatic hydrocarbons. The isotherms are expressed in percent loading on activated carbon as a function of the partial pressure. They were established at different temperatures.

Mr. Michael Manos
May 25, 1976
Page 2

You will also find enclosed papers describing the general adsorption correlation for aliphatic organics from which it is possible to expand the adsorption isotherms to conditions not shown on the enclosed tables and to calculate the isotherms of other hydrocarbons.

We hope that our data are useful. Please advise if there are any questions or additional ways in which we may assist.

Very truly yours,

Bernard L. Grandjacques

Bernard L. Grandjacques
Development Engineer

BLG:rmk

Enclosures

cc: Mr. Robert Kinne

SCOTT ENVIRONMENTAL TECHNOLOGY INC.
A SUBSIDIARY OF AMERICAN BIOCULTURE, INC

8600 CAJON BLVD
SAN BERNARDINO, CAL. 92411
(714) 887-2571

July 13, 1976

Mr. Blaine R. Joyce
Technical Service Director
Activated Carbon Products
Union Carbide Corporation
11709 Madison Avenue
Cleveland, Ohio 44107

Dear Blaine:

Earlier this year we contacted you to solicit technical information on activated carbon products. Upon review of the data received we have selected one or more of your products, as shown on the attached form, for further evaluation. We will be performing tests on the activated carbon to determine the working capacity in conjunction with various loading rates, stripping rates, temperatures, humidities, gasoline characteristics, etc.

Analyses of the results will be enhanced if we can relate our findings to carbon characteristics. We ask your assistance in providing the inspection data, specified on the attached form, for the actual batch of carbon we will be testing. Additionally, we are interested in knowing the relative costs for various carbons based on orders of 100 lbs., F.O.B. your warehouse.

Sincerely,

Michael J. Manos

Michael J. Manos
Project Engineer

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Attachment

ACTIVATED CARBON INSPECTION DATA FORM

Brand	UNION CARBIDE		
Product	MBV	MBV	MBV
Type	Coal	Coal	Coal
Form	Pell.	Pel.	Pell.
Mesh Size	12 x 20	4 x 6	6 x 10
Amount Required	25 lbs.	2 lbs.	2 lbs.
*Apparent Density, g/cc			
*Hardness			
*% Ash			
*% Moisture			
*Kindling Point, °c			
Pore Volume, cc/g			
Surface Area, m^2/g			
Iodine No.			
Activity, %CCl4			
Retentivity, %CCl4			
Cost/100 lbs.			

*These values may be "typical" numbers

SCOTT ENVIRONMENTAL TECHNOLOGY INC.
A SUBSIDIARY OF AMERICAN BIOCULTURE, INC.

2600 CAJON BLVD
SAN BERNARDINO, CAL. 92411
(714) 887-2571

July 11, 1976

Mr. Bernard L. Grandjacques
Activated Carbon Division
Calgon Corporation
Box 1346
Pittsburgh, Pennsylvania 15230

Dear Bernard:

Earlier this year we contacted you to solicit technical information on activated carbon products. Upon review of the data received we have selected one or more of your products, as shown on the attached form, for further evaluation. We will be performing tests on the activated carbon to determine the working capacity in conjunction with various loading rates, stripping rates, temperatures, humidities, gasoline characteristics, etc.

Analyses of the results will be enhanced if we can relate our findings to carbon characteristics. We ask your assistance in providing the inspection data, specified on the attached form, for the actual batch of carbon we will be testing. Additionally, we are interested in knowing the relative costs for various carbons based on orders of 100 lbs., F.O.B. your warehouse.

Sincerely,

Mike

Michael J. Manos
Project Engineer

rs

Attachment

P. S. Bob Kinne and I enjoyed having the opportunity to meet you during your recent trip to the West Coast. Your assistance has been extremely helpful, and the technical information on laboratory test techniques has been beneficial in solving some of our analytical problems.

ACTIVATED CARBON INSPECTION DATA FORM

	CALGON		
Brand			
Product	BPX		
Type	Coal		
Form	Gran.		
Mesh Size	8 x 30		
Amount Required	**		
*Apparent Density, g/cc			
*Hardness			
*% Ash			
*% Moisture			
*Kindling Point, °c			
Pore Volume, cc/g			
Surface Area, m^2/g			
Iodine No.			
Activity, %CCL4			
Retentivity, %CCL4			
Cost/100 lbs.	$0.71		

*These values may be "typical" numbers

**We currently have a 5-gallon container of BPX 8 x 30 labeled 1-86-931 (batch no.?) which is sufficient for the scheduled tests

SCOTT ENVIRONMENTAL TECHNOLOGY INC.
A SUBSIDIARY OF AMERICAN BIOCULTURES, INC.

2160 CABRIN BLVD
SAN BERNARDINO, CAL. 92411
(714) 887-2571

July 13, 1976

Mr. John R. Conlisk
Laboratory Supervisor
Product Development Department
Jci United States, Inc.
Wilmington, Delaware 19897

Dear John:

Earlier this year we contacted you to solicit technical information on activated carbon products. Upon review of the data received we have selected one or more of your products, as shown on the attached form, for further evaluation. We will be performing tests on the activated carbon to determine the working capacity in conjunction with various loading rates, stripping rates, temperatures, humidities, gasoline characteristics, etc.

Analyses of the results will be enhanced if we can relate our findings to carbon characteristics. We ask your assistance in providing the inspection data, specified on the attached form, for the actual batch of carbon we will be testing. Additionally, we are interested in knowing the relative costs for various carbons based on orders of 100 lbs., F.O.B. your warehouse.

Sincerely,

Michael J. Manos

Michael J. Manos
Project Engineer

ts

Attachment

ACTIVATED CARBON INSPECTION DATA FORM

	1C
Brand	DXL-0
Product	
Type	Lign.
Form	Gran.
Mesh Size	12 x 30
Amount Required	**
* Apparent Density, g/cc	
* Hardness	
* % Ash	
* % Moisture	
* Kindling Point, °c	
Pore Volume, cc/g	
Surface Area, m^2/g	
Iodine No.	
Activity, %CCl4	
Retentivity, %CCl4	
Cost/100 lbs.	

*These values may be "typical" numbers

**We currently have 20 lbs. of DXL-0-6425 on hand

A-2.

SCOTT ENVIRONMENTAL TECHNOLOGY INC.

A SUBSIDIARY OF AMERICAN BIOCULTURE, INC.

2000 OAKIN BLVD.
SAN BERNARDINO, CAL. 92411
(714) 887-2071

July 13, 1976

Mr. E. G. Polito
Environmental Services Engineer
Carbon Department
Chemical Division of Westvo
Covington, Virginia 24426

Dear Ed:

Earlier this year we contacted you to solicit technical information on activated carbon products. Upon review of the data received we have selected one or more of your products, as shown on the attached form, for further evaluation. We will be performing tests on the activated carbon to determine the working capacity in conjunction with various loading rates, stripping rates, temperatures, humidities, gasoline characteristics, etc.

Analyses of the results will be enhanced if we can relate our findings to carbon characteristics. We ask your assistance in providing the inspection data, specified on the attached form, for the actual batch of carbon we will be testing. Additionally, we are interested in knowing the relative costs for various carbons based on orders of 100 lbs., F.O.B. your warehouse.

Sincerely,

Mike

Michael J. Manna
Project Engineer

rs

Attachment

P. S. I enjoyed having the opportunity to meet with you at the APCA Convention in Portland and appreciate the assistance you have provided us on this program.

ACTIVATED CARBON INSPECTION DATA FORM

	WESTVACO		
Brand	WV-A		
Product	Wood		
Type	Gran.		
Form	14 x 35		
Mesh Size	5 lbs.		
Amount Required			
* Apparent Density, g/cc			
* Hardness			
* % Ash			
* % Moisture			
* Kindling Point, °c			
Pore Volume, cc/g			
Surface Area, m^2/g			
Iodine No.			
Activity, %CCL4			
Retentivity, %CCL4			
Cost/100 lbs.			

*These values may be "typical" numbers

ETHYL CORPORATION

Petroleum Chemicals Division
[illegible]

July 26, 1976

Scott Research Laboratories, Inc.
2600 Cajon Blvd.
San Bernardino, CA 92406

Attention: Mr. Dyrle Quick

Dear Mr. Quick:

We have received and tested your three samples of gasoline as you requested. Following are the results of our tests:

Sample Identification	1	2	3
Gravity, °API	57.3	56.3	62.7
Pb Content, g/gallon	2.78	0.017*	0.000*
Vapor Pressure, psi	8.9	8.7	13.8

*Pb Content by Atomic Absorption

Yours very truly,

B. M. Phillips
Laboratory Supervisor

R. C. Rickhoff

By: R. C. Rickhoff

RCR:dc
cc: R. T. Peterson

RECEIVED
JUL 27 1976
Scott Environmental Technology

RECEIVED
SEP 7 1976
Scott Environmental Technology

A-26

UNION CARBIDE CORPORATION
CARBON PRODUCTS DIVISION

September 1, 1976

Mr. Michael J. Manos
Scott Environmental Technology, Inc.
2600 Cajon Boulevard
San Bernadino, California 92411

Dear Mr. Manos:

The physical properties of the activated carbon samples you received for your gasoline vapor adsorption tests are as follows:

Carbon Grade	MBV			BEV
Mesh Size	12/28	8/10	4/6	12/28
Activity, %	58.7	61.3	68.9	66.4
Bulk Density, g	0.40	0.43	0.41	0.48
Hardness, %	95.6	97.8	98	94.3
Ash, %	5.9	5.7	--	6.2
Screen Analysis, %				
On 4 Mesh	-	-	0-10	-
On 6 Mesh	-	-	90-100	-
On 8 Mesh	-	0.4	0-10	-
On 10 Mesh	-	99.1	-	-
On 12 Mesh	0.2	0.4	-	2.7
On 14 Mesh	7.1	-	-	8.5
On 20 Mesh	55.8	-	-	67.4
On 28 Mesh	34.8	-	-	20.7
On Pan	2.1	0.1	0.1	0.7

I am arranging to send you the second lot of samples as you requested. If you have any questions, or if we can be of help, please let us know.

Very truly yours,

Blaine R. Joyce
Technical Service
Activated Carbon Products

BRJ/jj

Westvaco

September 26, 1975

RECEIVED
OCT - 3 1975
Scott Environmental Technology

Mr. Dyrle Quick
Scott Environmental Technology
2600 Cajon Boulevard
San Bernadino, California 92411

Dear Mr. Quick:

In reference to our previous phone conversation, I have recently been in contact with Don Tolles of our Charleston Research Laboratory. Don has done quite a bit of work on refueling vapor loss control with activated carbon and holds several patents. Two of Don's reports that should be of particular interest to you are not available for out-of-company distribution. However, it is possible to send you some excerpts from these reports, notably data on working capacity and general regeneration techniques applied.

Looking at the earliest of the two reports (December 19, 1972) and referring to figure 3, please note the following conditions:

influent vapor concentration = 3%

equilibrium loading = 17.5% (80°F)

regeneration temp. = 200°F

regeneration vacuum = 27" Hg

gives working capacity of 7%

"bleed" = 2 residual butane in air = 0.25% (point C)

In the report dated July 10, 1973, note that saturation capacity has been raised to a maximum of 23.4%, leaving an adjusted working capacity of

Chemical Division
Carbon Technical Center
Covington, Virginia 24426
Telephone 703 962 2111

greater than 16%. Note, also, though, that we are using a thinner bed of carbon as well as higher regeneration temperatures (269-295°F). The original report discusses the experimental results of three methods of regeneration: vacuum, air purge at atmospheric pressure; and reduced pressure air purge, of which vacuum regeneration applies the smallest load on vapor recovery equipment. This report also discusses the Model II prototype canister dimensions (which is not available for release). Essentially, this is a suitcase-type adsorber--portable, and designed to be used in multiples, connected in series or parallel combinations at service station sites for adsorption of vented fuel vapors.

As you can see, Westvaco has been very active in this field; and very comprehensive testing has been done using our carbons. If further interest in controlling refueling vapor losses arises, I suggest that you get back in touch with me, Mr. Quick.

Look over the enclosed material and product data bulletins carefully. I sincerely hope that I have successfully covered all of the points in question.

Sincerely,

Edward G. Poltto
Environmental Services Engineer

EGP/ckl

Enclosures

APPENDIX B, Matrix

Test No:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Carbon:	W-1 UCAR MBV 12 x 28	X	X											X	X	X	X
	W-2 UCAR MBV 8 x 10						X					X					
	W-3 UCAR MBV 4 x 6												X				
(react)	W-4 UCAR MBV 12 x 28										X						
(diff., batch)	W-5 UCAR MBV 12 x 28					X				X							
(satur)	W-6 UCAR MBV 12 x 28								X								
	X-1 CALGON BPX 12 x 30				X												
(satur)	X-2 CALGON BPX 12 x 30							X									
	Y-1 WESTVACO 14 x 35			X													
	Z-1 I.C.I. 12 x 30				X												
	W-7 UCAR SFV 12 x 28									X							
Canister:	H x A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	2H x A																
	H x 2A																
Fuel:	A 9# RVP Leaded	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	B 9# RVP Unleaded																
	C 14# RVP Unleaded																
Purge:	1-1 75° F. Air 4000cc/m	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	1-3 150° F. Air 4000cc/m																
	1-4 200° F. Air 4000cc/m																
	1-5 75° F. Air 20,000cc/m																
	1-6 75° F. Air 40,000cc/m																
	2-1 VAC @ 75°F, abs. 100 mm																
	2-2 VAC @ 150°F, abs. 100 mm																
	2-3 VAC @ 200°F, abs. 100 mm																
	2-4 VAC @ 75°F, abs. 25 mm																
Ambient:	75° F. Dry Air	X	X	X	X	X	X	X	X	X	X	X					
	50° F. Dry Air												X				
	90° F. Dry Air													X			
	75° F. 40% R.H.														X		
	75° F. 80% R.H.															X	

Test No:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Carbon: W-1 UCAR MBV 12 x 28	X	X	X	X	X	X	◀				X	(1)				▶
W-2 UCAR MBV 8 x 10																
W-3 UCAR MBV 4 x 6																
(react) W-4 UCAR MBV 12 x 28																
(diff, batch) W-5 UCAR MBV 12 x 28																
(satur) W-6 UCAR MBV 12 x 28																
X-1 CALGON BPX 12 x 30																
(satur) X-2 CALGON BPX 12 x 30																
Y-1 WESTVACO 14 x 35																
Z-1 I.C.I. 12 x 30																
Canister: H x A	X			X	X	X	◀				X					▶
2H x A		X														
H x 2A			X													
Fuel: A 9# RVP Loaded	X	X	X	X	X	X	◀				X					▶
B 9# RVP Unleaded																
C 14# RVP Unleaded																
Purge: 1-1 75° F, Air 4000cc/m	X	X	X			X	◀				X					▶
1-3 150° F, Air 4000cc/m																
1-4 200° F, Air 4000cc/m																
1-5 75° F, Air 20,000cc/m				X												
1-6 75° F, Air 40,000cc/m					X											
2-1 VAC @ 75°F, abs. 100 mm																
2-2 VAC @ 150°F, abs. 100 mm																
2-3 VAC @ 200°F, abs. 100 mm																
2-4 VAC @ 75°F, abs. 25 mm																
Ambient: 75° F, Dry Air	X	X	X	X	X	X	◀				X					▶
50° F, Dry Air																
90° F, Dry Air																
75° F, 40% R.H.																
75° F, 80% R.H.																

(1) 1000 cycle degradation test

TEST CELL #2

Test No:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Carbon:																
W-3 UCAR MBV 12 x 28	X	X	X	X	X	X	X				X	X				
W-2 UCAR MBV 8 x 12																
W-3 UCAR MBV 4 x 6																
(react) W-4 UCAR MBV 12 x 28																
(diff. batch) W-5 UCAR MBV 12 x 28																
(satur) W-6 UCAR MBV 12 x 28																
X-1 CALGON BPX 12 x 30								X	X	X			X	X	X	X
(satur) X-2 CALGON BPX 12 x 30																
Y-1 WESTVACO 14 x 35																
Z-1 I.C.I. 12 x 30																
Canister:																
H x A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2H x A																
H x 2A																
Fuel:																
A 9# RVP Leaded	X	X	X	X							X	X	X	X		X
B 9# RVP Unleaded									X							
C 14# RVP Unleaded					X	X	X	X	X						X	
Purge:																
1-1 75° F, Air 4000cc/m	X								X							
1-3 150° F, Air 4000cc/m																
1-4 200° F, Air 4000cc/m																
1-5 75° F, Air 20,000cc/m																
1-6 75° F, Air 40,000cc/m																
P-1 VAC @ 75°F, abs, 100 mm		X	X													
P-2 VAC @ 150°F, abs, 100 mm						X	X			X		X				
P-3 VAC @ 200°F, abs, 100 mm				X							X		X	X		
P-4 VAC @ 75°F, abs, 25 mm			X		X			X								X
Ambient:																
75° F, Dry Air	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
60° F, Dry Air																
90° F, Dry Air																
75° F, 40% R.H.																
75° F, 80% R.H.																

TEST CELL #3

Test No:

4 -	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Carbon:

W-1 UCAP MBV 12 x 28	X	X	X	X	X	X				X				X	X	X
W-2 UCAR MBV 8 x 10																
W-3 UCAR MBV 4 x 6																
(react) W-4 UCAR MBV 12 x 28																
(diff, batch) W-5 UCAR MBV 12 x 28																
(satur) W-6 UCAR MBV 12 x 28																
X-1 CALGON BPX 12 x 30							X	X			X	X	X			
(satur) X-2 CALGON BPX 12 x 30																
Y-1 WESTVACO 14 x 35									X							
Z-1 I.C.I. 12 x 20																

Canister:

H x A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2H x A																
H x 2A																

Fuel:

A 9# RVP Leaded	X	X	X	X					X		X	X	X	X	X	X
B 9# RVP Unleaded										X						
C 14# RVP Unleaded					X	X	X	X								

Purge:

1-1 75° F, Air 4000cc/m	X	X			X		X		X	X	X			X		
1-3 150° F, Air 4000cc/m			X			X		X				X			X	
1-4 200° F, Air 4000cc/m				X									X			X
1-5 75° F, Air 20,000cc/m																
1-6 75° F, Air 40,000cc/m																
2-1 VAC @ 75°F, abs. 100 mm																
2-2 VAC @ 150°F, abs. 100 mm																
2-3 VAC @ 200°F, abs. 100 mm																
2-4 VAC @ 75°F, abs. 25 mm																

Ambient:

75° F, Dry Air	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
50° F, Dry Air																
90° F, Dry Air																
75° F, 40% R.H.																
75° F, 80% R.H.																

TEST CELL #4

APPENDIX C--TEST RESULTS

Test	Date 1976	Cycles	Last Capacity gms	Bed Size gms	Working Capacity gms/100 gms	Vapor Concentration %	Corrected* gms/100
1-1	8/20	Z1	10.00	170	5.88	52	5.93
1-2	9/17	Z1	9.25	160	5.78	52	5.83
1-3	9/02	Z1	13.70	120	11.42	55	11.37
1-4	8/27	Z2	6.88	160	4.30	56	4.22
1-5	8/19	Z1	8.70	160	5.44	52	5.49
(2)1-11	9/25	Z1	7.95	160	4.97	53	4.94
1-7	8/25	Z1	5.67	160**	3.54	50	3.69
1-8	9/05	Z1	7.30	160**	4.56	52	4.58
1-9	9/13	Z1	7.15	160	4.47	52	4.52
1-10	9/16	Z1	10.60	149.3	7.10	53	7.12
1-11	9/07	Z2	7.45	160	4.66	54	4.64
1-12	8/26	Z1	8.60	160	5.38	57	5.26
1-13	9/20	Z2	7.95	160	4.97	30	5.70
1-14	9/21	Z1	10.40	160	6.50	62	6.21
1-15	9/14	Z1	7.75	158.25[A]	4.90	52	4.95
1-16	9/15	Z2	9.30	152.95[B]	4.65	53	4.69

*Corrected to 53.96% Vapor Concentration

**Moisture equilibrated but not yet vapor saturated

[A]Moisture equilibrated @ 42%

[B]Moisture equilibrated @ 80%

TEST RESULTS

Test	Date 1976	Cycles	Lost Capacity gms	Bed Size gms	Working Capacity gms/100 gms	Vapor Concentration %	Corrected* gms/100
2-1	8/20	21	9.42	160	5.89	55	5.84
2-2	8/23	21	21.75	320	6.80	55	6.77
2-3	8/25	21	18.42	320	5.76	53	5.77
2-4	9/16	21	7.40	160	4.94	52	4.96
2-5	9/16	21	8.25	160	5.16	52	5.21
2-6	9/02	21	9.70	160	6.06	50	6.19
2-7	9/03						
thru	thru						
2-1a	9/14	1023	7.00	160	4.38	53	4.39

*Corrected to 51.96% vapor concentration

TEST RESULTS

Test	Date 1976	Cycles	Last Capacity gms	Bed Size gms	Working Capacity gms/100 gms	Vapor Concentration %	Corrected* gms/100
3-1	8/20	21	9.45	150	5.91	96	5.83
3-2	8/25	21	8.61	160	8.39	55	8.33
3-3	8/27	21	2.10	160	1.31	51	1.40
3-4	8/26	21	6.27	160	3.92	54	3.90
3-4	9/03	1	6.30	160	3.94	50	4.05
3-4	9/07	1	6.10	160	3.81	51	3.90
3-4	9/08	1	6.94	160	4.34	51	4.42
3-5	9/15	1	11.40	160	7.13	97	7.26[1]
3-6	8/24	21	8.35	160	5.27	97	5.42[1]
3-6	9/15	1	7.90	160	4.94	97	4.57[1]
3-7	9/15	1	8.60	160	5.38	97	5.42[1]
3-8	9/16	1	7.65	160	4.91	94	5.05[1]
3-9	9/16	1	8.55	160	5.34	94	5.49[1]
3-10	8/19	21	8.36	160	5.04	96	8.46
3-11	9/03	1	8.35	160	5.22	50	5.33
3-11	9/07	1	8.50	160	5.31	51	5.40
3-11	9/09	1	9.61	160	6.01	51	6.09
3-12	9/03	1	10.35	160	6.47	50	6.58
3-12	9/07	1	10.60	160	6.63	51	6.71
3-12	9/08	1	11.11	160	6.97	51	7.06

*Corrected to 53.4% vapor concentration

[1]Corrected to 98.0% vapor concentration

TEST RESULTS

Test	Date 1976	Cycles	Last Capacity gms	Bed Size gms	Warming Capacity gms/100 gms	Vapor Concentration %	Corrected gms/.3B
3-13	9/06	1	7.30	160	4.56	51	4.65
3-13	9/10	1	10.35	160	6.47	50	6.59
3-13	9/13	1	8.20	160	5.13	50	5.24
3-14	9/09	1	9.80	160	6.13	51	6.27
3-14	9/10	1	11.15	160	6.97	50	7.06
3-14	9/13	1	9.70	160	6.06	50	6.18
3-15	9/16	1	9.30	160	5.81	96	5.95[1]
3-16	9/09	1	5.40	160	3.38	51	3.45
3-16	9/10	1	5.90	160	3.69	50	3.80
3-16	9/13	1	6.50	160	4.06	50	4.18

[1]Corrected to 96 vapor concentration

TEST RESULTS

Test	Date 1976	Cycles	Last Capacity gms	Bed Size gms	Working Capacity gms/100 gms	Vapor Concentration %	Corrected* gms/100
4-1	8/21	21	9.67	160	6.17	51	6.19
4-2	8/23	21	9.67	160	6.17	54	6.15
4-3	9/02	21	10.10	160	6.31	51	6.40
4-4	9/03	21	9.00	160	5.63	46	5.82
4-5	9/15	21	10.70	160	6.69	98	6.69[1]
4-6	9/16	21	10.15	160	6.34	95	6.44[1]
(3)4-7	9/17	21	10.70	160	6.38	98	6.52[1]
4-8	9/17	21	10.10	160	6.31	98	6.45[1]
(2)1-3	9/17	21	13.65	120	11.38	53	11.36
4-10	9/25	21	8.31	160	5.19	55	5.15
4-11	9/29	21	8.96	160	5.60	53	5.62
4-12	9/07	23	7.50	160	4.69	48	4.57
4-13	9/08	21	8.70	160	5.44	47	5.65
4-14	9/13	22	10.30	160	6.44	54	6.26
4-15	9/09	21	10.05	160	6.28	47	6.49
4-16	9/10	21	10.05	160	6.28	52	6.42

*Corrected to 53.4% water concentration

[1]Corrected to 98.5% water concentration

APPENDIX B

Carbon Specifications

AUTOMATIC CARBON INSPECTION DATA PUMP

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
							Check Test #-2	
TYPE	[illegible]	[illegible]	Coal	Coal	Coal	Coal	Coal	Coal/Wood
TYPE	Grain	Grain	Grain	Grain	Pellet	Pellet	Grain	Grain
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]						
[illegible]	[illegible]	[illegible]	[illegible]					
[illegible]	[illegible]							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible]	[illegible]	[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]			[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]					

*These values may be "typical" numbers